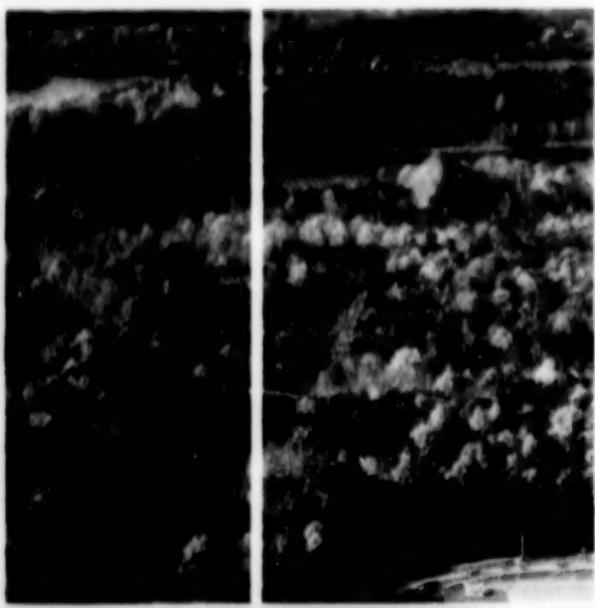




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PROCEEDINGS  
OF THE  
INTERNATIONAL  
SYMPOSIUM  
ON THE  
FORENSIC ASPECTS  
OF MASS DISASTERS  
AND CRIME SCENE  
RECONSTRUCTION



FBI ACADEMY  
QUANTICO, VIRGINIA  
JUNE 23-29, 1990

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**Proceedings  
of the  
International Symposium  
on the  
Forensic Aspects of Mass Disasters  
and Crime Scene Reconstruction**



Host  
Laboratory and Identification Divisions  
Federal Bureau of Investigation

June 23-29, 1990

**Forensic Science Research and Training Center  
FBI Academy  
Quantico, Virginia**

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## FORWARD

On June 23-29, 1990, the FBI Laboratory and Identification Divisions co-hosted an "International Symposium on the Forensic Aspects of Mass Disasters and Crime Scene Reconstruction" at the FBI Laboratory's Forensic Science Research and Training Center, FBI Academy, Quantico, Virginia. This symposium was attended by 302 scientists from industry, academia and law enforcement laboratories from Australia, Canada, the Federal Republic of Germany, Finland, Israel, the Marshall Islands, Mexico, Saudi Arabia, Trinidad and Tobago, the United Kingdom and nearly every state in the United States. When the topic area for this symposium was selected, we identified a panel of individuals considered to have expertise in many diverse fields to assist in planning the program and identifying the plenary speakers. Representatives from the following organizations served on the planning committee: the National Transportation Safety Board; the Federal Emergency Management Agency; the Armed Forces Institute of Pathology; the National Association of Medical Examiners; the Connecticut State Police; Georgia Police Academy, The International Association of Identification and the FBI.

This particular topic, mass disasters and crime scene reconstruction, attracted a great deal of interest from a wide spectrum of associated professional disciplines. When the meeting announcement and call for abstracts was sent out, we received nearly 450 applications seeking the 200 available invitations which remained after all the presenters were identified. The program committee reviewed over 80 excellent abstracts, of which only one-half could be utilized due to space limitations at the poster sessions.

We sincerely hope that the exchange of information and ideas at this symposium will generate interest into future research in the forensic aspects of mass disasters and crime scene reconstruction. We in the FBI will continue to sponsor symposia in the various scientific disciplines in an effort to provide a forum for the transfer of technology.

On behalf of the FBI, we would like to thank all those who participated in making this symposium a success.

Lawrence K. York  
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**SECTION I**  
**LECTURES**

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## STATE EMERGENCY PLANS

*Addison E. Slayton, Jr.*

Virginia Department of Emergency Services  
Richmond, Virginia

The intent of this paper is to discuss state emergency plans and an overall approach to emergency management as practiced in the Commonwealth of Virginia.

Our philosophy of planning is predicated on three simple premises:

(1) Mission-type orders. Our plans outline generally what must be done, but do not tell the plan holder exactly how to go about doing it

(2) Our plans provide a written blueprint for detailed preparedness, response and recovery actions. As Eisenhower once said, "plans are nothing, but planning is everything"

(3) We believe that it is better to have a plan and not need it than to need a plan and not have it. In other words, prudence demands that, in our business, you must have a plan.

The Virginia Department of Emergency Services (DES) has as its mission the preparedness for, response to, recovery from, and mitigation of natural, man-made, and war-caused disasters. The preparedness part consists of planning, training, exercising, and equipping of response and recovery entities to accomplish their disaster responsibilities. The response portion of the mission is primarily one of coordination of the state's disaster response resources—with one exception. Further, DES has a capability for direct response, if requested by local government, to hazardous materials incidents of all types, to include transportation accidents, oil spills, toxic releases, cleanup of dumps, and the like. Beyond this, our response mission is to coordinate the emergency activities of other state agencies with the needs of local governments. The recovery part of our mission addresses actions, in concert with the federal government, concerning public and individual assistance programs in presidentially-declared disasters. Mitigation alludes to an emergency program which entails measures which, if properly funded and adopted, will remove or lessen the effects of conditions which contribute to disasters.

The DES has as its authority for existing and operating, the Commonwealth of Virginia (COV) Emergency Services and Disaster Law, 1973, Code of Virginia, as amended. This document stipulates that the Governor is the Director of Emergency Services for the state and the Coordinator of Emergency Services can act for him in the conduct of disaster operations statewide. Consequently, the Coordinator of Emergency Services is a

gubernatorial appointee. Virginia law further provides that each local jurisdiction in the state also have a director and a coordinator of emergency services. Thus, we have an appointed point of contact in each jurisdiction with whom we can work in emergency management matters. Also under the law, the DES is organized to provide assistance and advice to local governments in such areas as planning, training and exercising and operational matters. This includes hazardous materials, radiological instrumentation, and telecommunications as well as public information and individual program management. The state has been divided into four geographical regions, with each served by a regional coordinator and a hazardous materials officer, to facilitate accomplishment of these emergency management activities. The inclusion of hazardous materials response is one of the ways the Virginia Department of Emergency Services differs from most other state emergency management agencies.

The DES conducts its business by way of a series of relationships. A primary one is with the Governor who, as Director of Emergency Services, has emergency powers under the law which are either implied or specifically delineated. For instance, the Governor may declare a State of Emergency to exist by issuing an executive order in those affected areas of the Commonwealth. By so doing, he authorizes state agencies to respond to the disaster under the direction of the state coordinator. He also opens the state coffers to pay for the unprogrammed expenses associated with the disaster response. This formal declaration of an emergency is also a prerequisite for the Governor requesting federal disaster aid, if needed, from the President of the United States. As an aside and because some of you are citizens of Virginia, you may be interested in knowing that payment for nonfederally declared disasters in Virginia comes directly from the general fund. There is no dedicated disaster fund available in this state as is the case in some other states. To quote from the law, "... the Governor is authorized to expend from all funds of the State Treasury not constitutionally restricted, a sum sufficient." That is, we will spend whatever it takes to meet disaster obligations.

Another important relationship we have is with other state agencies. We must work closely with over 40 agencies who have specific taskings in our plans for some aspect of disaster assistance. Some are considered pri-

mary agencies, such as the state police, the national guard, the health department, the transportation department, etc. These are the direct responders due to their functional capabilities and the fact that they have personnel and resources spread throughout the state. Other agencies have diverse support roles and others provide specialized assistance in the form of technical advice or testing. To ensure total cooperation from these entities, each of our state-level plans is promulgated by an executive order signed by the Governor which enjoins all tasked agencies to cooperate in disaster operations. This action saves a lot of time and trouble when the "balloon goes up."

Another relationship we have is with the localities of the Commonwealth. As previously noted, we do have a point of contact in each jurisdiction in the person of the local coordinator. The local coordinator is not a state employee. They are appointed by local government and are supervised at that level. Nevertheless, these individuals serve as our liaison with the elected heads of local government and perform other emergency management duties. In return for this service, DES provides them with individual job training and other assistance in the form of planning, hazardous materials response equipment, search and rescue advice and training, etc. We also act as a conduit and administrator for emergency management assistance (EMA) funds, which are provided by the federal government for the state and for selected localities.

One final relationship, which is certainly an important one, is with federal government agencies. Our primary federal contact is with the Federal Emergency Management Agency (FEMA). The EMA funds just mentioned are provided by FEMA. It also funds—wholly or in part—several separate programs having to do with planning, radiological instrument calibration, training and exercises, communications and warning and floodplain management. Perhaps best known is the federal disaster relief program through which FEMA provides funds to state and local governments in presidentially-declared disasters for the restoration of damaged public property and to individuals to assist with their disaster losses. We also deal with the Environmental Protection Agency (EPA) on many hazardous materials matters; with the Nuclear Regulatory Commission (NRC) concerning preparedness for response to an accident involving a nuclear power plant; with the U. S. Army Corps of Engineers (COE) on mitigation, public assistance, and hurricane preparedness; with the Small Business Administration (SBA) on small, undeclared disasters; with the U. S. Department of Agriculture (USDA) on drought relief; with the National Weather Service (NWS) on severe weather warnings; and so on.

All of the foregoing relationships are spelled out in

some degree of detail in our state emergency operations plans. As stated earlier, in our plans we try not to outline exactly how an assigned task should be accomplished. We depend instead upon requiring the agencies/governments so tasked to develop their own internal Standing Operating Procedures (SOPs) in order to provide detailed, "how-to" steps designed to accomplish a specific mission as it best suits that entity. Our state plans follow a standard, abbreviated military-style format with functional annexes, and supporting appendices, tabs, maps, matrixes, etc. These plans are open-ended, with protective measures designed to be applicable to almost any hazard. Of necessity, there are some hazard-specific plans, such as radiological emergency response and oil spill and hazardous materials response plans, primarily because they are funded under varying programs of both private and public sources. Fundamentally, plans are generic or all-hazard in their structure.

The State Emergency Operations Plans (EOPs) also serve as the umbrella for development of local emergency operations plans, which are required for political subdivisions not only by Virginia state law but by federal regulations. Local plans are tailored to address locally-specific hazards, using local organization, local resources, etc. However, they also must interface with state plans just as state plans must interface with federal plans. This is particularly true as regards federal/state recovery programs and procedures, to include such items as damage assessment, training/exercise parameters, telecommunications, mitigation measures as well as disaster assistance.

In the litigious times in which we live, no one can afford to overlook the issue of liability. The specter of lawsuits growing out of emergency operations is something one can ill afford to ignore and that protection in this area may well begin with the emergency planning process.

The planning process is not likely to provoke many lawsuits, but emergency operations might. If harm is done in the course of an emergency response and the cause can be linked to responder actions, liability issues may soon follow. Questions regarding training and supervision of emergency workers might be raised and the immunity from liability defense may not be permitted in suits brought against governments or other emergency action organizations.

The point to make with the liability issue is that a carefully developed emergency plan that is based on appropriate legislation can be the first step in a legal defense or better, avoid the problem in the first place. Such plans will spell out who is to do what and will not task agencies and organizations with inappropriate missions for which they are not trained and are, therefore, more likely to make costly mistakes. This can be espe-

cially true where private volunteer organizations are involved. The question is not one of willful misconduct, which is usually excepted from immunity protection, but rather one of propriety if the individual or unit is inappropriately assigned to the emergency task at hand. Good plans properly executed and carefully followed can help avoid these liability issues.

Liability is a real issue and one of emerging concern for emergency managers, heads of government, and for those in the private sector that accept emergency response roles.

Plans are the bedrock upon which emergency management is practiced. Plans provide for the coordinated emergency response of all public and private agencies whether they be at the federal, state, or local level. Merely having plans, however, is not enough. There are five basic elements that make for plans that work.

- (1) They should be rooted in law.

- (2) They must be read, accepted, and used by all tasked agencies/organizations. The best way to ensure acceptability is to have the tasked entities develop their own task assignments.

- (3) They must be regularly exercised to ensure functionality.

- (4) They must be regularly updated based on problems uncovered during exercises or actual operations, based on changes in the law, organization changes, or changes in procedures.

- (5) They should be implemented, where necessary, with specific standard operating procedures.

As previously discussed, emergency operations plans should be like mission-type orders in that they indicate what is to be done without directing how the job is to be accomplished. We cannot plan for every conceivable incident, nor can we anticipate the magnitude and complexity of every possible event. Emergency plans are not straitjackets to be blindly and unerringly followed without regard for their applications to the incident at hand. Emergency plans should be an outline of previously-arranged task assignments, formerly-established relationships and procedures, and an indication of documented capabilities, all of which are to be used as the situation demands. In other words, emergency plans should be flexible documents that enhance operations and not hamstring them.

In summary, emergency management in Virginia consists of the mutually-supporting elements of disaster preparedness, response, recovery, and mitigation. These elements are addressed in, and have their basis for action contained in the Emergency Operations Plans (EOPs) developed and distributed by the Virginia Department of Emergency Services to state and federal agencies and to local jurisdictions throughout the state. Local EOPs are developed, based upon the state models, and though locally-specific, they interface with state plans. All of these actions and plans are promulgated by executive orders signed by the Governor which have the force and effect of law. The Virginia Emergency Services and Disaster Law serves as the legal basis and authority for all Department activities.

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## FEDERAL EMERGENCY PLANS

*Grant C. Peterson*

Federal Emergency Management Agency  
Washington, D. C.

The Federal Emergency Management Agency (FEMA) was established by executive order 11 years ago to coordinate emergency planning. Federal emergency management activities are coordinated by FEMA for all types of disasters—natural and technological, and national security as well—and to provide technical and financial assistance to state and local governments to carry out their own emergency management programs. Today, the agency has some 2,300 professional and support personnel located at FEMA Headquarters in Washington, D.C. and in its ten regional offices.

Emergency planning, at whatever level of government, has one goal: to provide an effective and efficient emergency response. The first responder in any disaster, regardless of its nature, is local government. If the resources of local government are overwhelmed by the emergency, the next responder to step in is the state. And if the state and affected local governments cannot adequately respond, then—and only then—does the federal government step in. Therefore, before we address federal emergency planning, we have to understand that the federal government's role in most cases complements the critical work of state and local governments rather than supplants it.

The Federal Emergency Management Agency plays a significant role in the development of all-hazard state and local emergency operations plans. Funded through the Civil Defense program, this planning describes the actions necessary to protect life and property in the event of a disaster of any kind. The plans identify authorities, relationships, and the actions that must be taken to prepare for, respond to, and recover from a disaster. Based on predetermined assumptions, objectives, and existing capabilities, the plans assign responsibilities for emergency operations and define how, when, and where they will be accomplished. They constitute the essential basis for prompt, coordinated response by government when any national security, technological or natural disaster strikes. In addition to these all-hazard plans, FEMA also assists state and local government planning efforts through its hazard-specific programs which build preparedness for the unique aspects of radiological emergencies, hazardous materials, earthquake and hurricanes, and dam safety.

Without capabilities, however, plans would simply be stacks of worthless paper. Therefore, FEMA assists, through the Civil Defense program, in funding for emer-

gency operating centers, warning and communications systems, radiological monitoring instruments, electromagnetic pulse protection and other hardware capabilities, as well as identifying shelters. Another essential component, a trained cadre of professionals, is partially funded through the Civil Defense program, which also contributes to the salaries of the state planners and local emergency program managers of 3,400 participating local jurisdictions. Further assistance is available to these critical personnel in the form of training and exercise planning.

Dwight D. Eisenhower stated in a 1957 speech, "Plans are worthless . . . planning is everything . . . Keep yourself steeped in the character of the problem you may one day be called upon to solve—or to help to solve." Planning cannot be translated into capability by developing a paper plan and putting it on the shelf. For planning to be effective, and capability-building to be credible, they must be continuing activities for the people who have to implement the plans when emergencies occur.

What has just been described is the state and local side of the equation. But what is the response role of the federal government when a disaster strikes of such magnitude that it overwhelms the affected local governments, and the state's ability to respond? And how does planning help prepare the federal government to lend its resources to an effective and coordinated response?

To explain this process, here is a brief snapshot of what the federal government does when the governor of a disaster-stricken state asks for federal assistance from the President.

The governor's request typically includes a damage estimate, a listing of the state's resources, and the federal disaster assistance believed to be needed. The request is evaluated by FEMA which then forwards a recommended course of action to the President.

If a presidential declaration is made, FEMA appoints a federal coordinating officer who coordinates all the federal disaster assistance programs available. A disaster field office is set up to provide a central point for coordination; and Disaster Application Centers (or DACs) are established as places where individuals can apply for assistance. These DACs are one-step centers staffed by FEMA personnel and representatives from other federal agencies, the American Red Cross, and various state and local agencies. (As a result of Hurri-

cane Hugo and the Loma Prieta Earthquake, for example, FEMA's DACs had taken over 387,000 registrations and processed over 366,000 disaster assistance checks to individuals totaling almost \$642 million.) The kinds of individual assistance available in disaster applications centers includes Small Business Administration loans to individuals and businesses for the repair or replacement of property; FEMA Individual and Family Grants; funds for housing and furniture expenses; disaster unemployment assistance; crisis counseling; and help to meet medical and funeral expenses.

In addition to these kinds of individual assistance, FEMA also provides public assistance to the state, local jurisdictions, and qualifying private nonprofit organizations for myriad recovery activities: clearance of debris, when in the public interest; emergency protective measures for the preservation of life and property; repair or replacement of roads, bridges, dikes, irrigation works, drainage facilities, public buildings and related equipment, and public utilities.

As noted, the activities just described are carried out in the recovery phase of a disaster and constitute the typical operation associated with a Presidential declaration. In an average year, 23 disasters are declared; and in the so-called average disaster, the federal government helps approximately 2,800 applicants receiving a total of some \$9 million worth of assistance.

This, then, is the usual context of emergency planning and response as viewed from the national perspective; plans generally anticipate how the federal government will support rather than supplant state and local response efforts.

In the Hurricane Hugo disasters, however, FEMA found that a state or territorial government itself may become a victim of the disaster, thus substantially enlarging the federal role. And certainly in any catastrophic event an earthquake or nuclear attack, for example this has always been recognized in planning. For this reason, the "Plan for Federal Response to a Catastrophic Earthquake" provides a good example of the federal emergency planning process.

Short of a strategic nuclear attack, the earthquake hazard is viewed as potentially having the most devastating consequences for the United States. A few earthquake facts support this contention:

- Earthquakes are a threat to the entire nation.
- Research shows that all states and territories are subject to earthquakes. Thirty-nine have a moderate to high risk, and 17 are currently classified as high risk.
- Although never heard because most of them are insignificant, earthquakes occur somewhere in the U. S. every day.
- October 17, 1989, the Loma Prieta earth-

quake, measuring 7.1 on the Richter Scale, struck in Northern California. It was the largest earthquake to occur in this country since the 1906 San Francisco earthquake, which measured 8.3. Loma Prieta resulted in 62 deaths, compared to 2,500 in the 1906 quake. Physical damages from the Loma Prieta earthquake have exceeded \$6 billion, placing it near the top of the list of the most expensive natural disasters in the U. S.

As tragic as it was, however, the Loma Prieta Earthquake was not a catastrophic earthquake. Fortunately, the U. S. thus far has been spared a truly catastrophic earthquake—but the clock is ticking. It is not a question of if, but when. For example, scientists are predicting:

- A 60% probability that a Richter magnitude 7.5 or greater earthquake will occur on the San Andreas Fault in Southern California in the next 30 years.
- A 50% probability that a 7.0 or greater earthquake will occur on the San Andreas Fault in the San Francisco Bay area in the next 30 years.
- A 40-63% probability that a 6.0 or greater earthquake will occur on the New Madrid Fault in the Central U. S. before the year 2000.
- A 50% probability that a 6.0 or greater earthquake will occur in the Eastern U. S. in the next 30 years.

A catastrophic earthquake in the U. S. would quickly exhaust state and local response resources and result in numerous casualties, high property loss, and severe disruption of transportation systems and the economic infrastructure.

Secondary effects such as fires, floods, and hazardous materials spills would compound the damage. Additionally, there is the potential for aftershocks which could lead to further damage of already weakened structures.

The federal government would be called upon almost immediately to support state and local governments in their efforts to save lives and protect property, and would use its Plan for Federal Response to a Catastrophic Earthquake. This plan provides for immediate and massive assistance from the federal government to respond to a catastrophic earthquake—or other natural event—in the U. S. It outlines policies, planning assumptions, a concept of operations, an organizational structure, and specific federal department and agency responsibilities. It establishes a framework for coordinating the broad spectrum of federal government assistance that will be needed to supplement local and state efforts—assistance such as search and rescue teams, medical resources, and other specialized support.

Twenty-six federal agencies are involved in this earthquake response planning, including all 14 cabinet departments. The American Red Cross is also included, and is considered a federal agency for purposes of the plan. The types of help the federal government could provide under the plan are grouped into eleven emergency support functions which reflect the kinds of support state and local governments will certainly need: transportation, communications, construction management, firefighting, damage information, mass care, resource support, health and medical services, urban search and rescue, hazardous materials, and food.

Each function is headed by a primary federal agency, with other federal agencies providing support as necessary. Primary agencies have been assigned on the basis of which department or agency possesses the most resources and capabilities in the pertinent functional area. The U. S. Army Corps of Engineers, for example, is the logical primary agency for construction management, and so is assigned lead responsibility in that area.

While the plan is generic for the entire country, it also serves as the basis for addressing the site-specific requirements within each of the high-risk, high-population areas in the nation. Nine of FEMA's ten regional offices are coordinating the development of plan supplements for the high-risk areas in their respective regions.

What would actually happen following the occurrence of a major earthquake?

FEMA would expedite a request from the governor of the affected state for a disaster declaration, while, simultaneously, efforts would be under way to determine the extent of damages. If the earthquake were catastrophic, FEMA would implement the plan; if, however, there were some uncertainty as to the true scope of the disaster, FEMA would partially implement the plan, activating emergency support functions on an as-needed basis.

At FEMA Headquarters, an interagency emergency support team, composed of the 11 primary agencies, would gather to assume national-level coordination of emergency operations and provide support to the response structure in the field.

Likewise, an interagency catastrophic disaster response group would be convened to facilitate decision-making on major policy issues and resource problems. The group is composed of senior officials from all the federal agencies that are signatory to the plan. In the field, the primary federal agencies for the eleven emergency support functions would automatically deploy personnel and resources to disaster staging areas in the affected states in anticipation of receiving requests for federal assistance from the state.

Figure 1 illustrates the proposed organizational prototype for a typical recovery operation in a small disaster. The federal coordinating officer's immediate staff carries out public information, congressional relations, community liaison, and outreach responsibilities. These

## LEVEL I (RECOVERY)

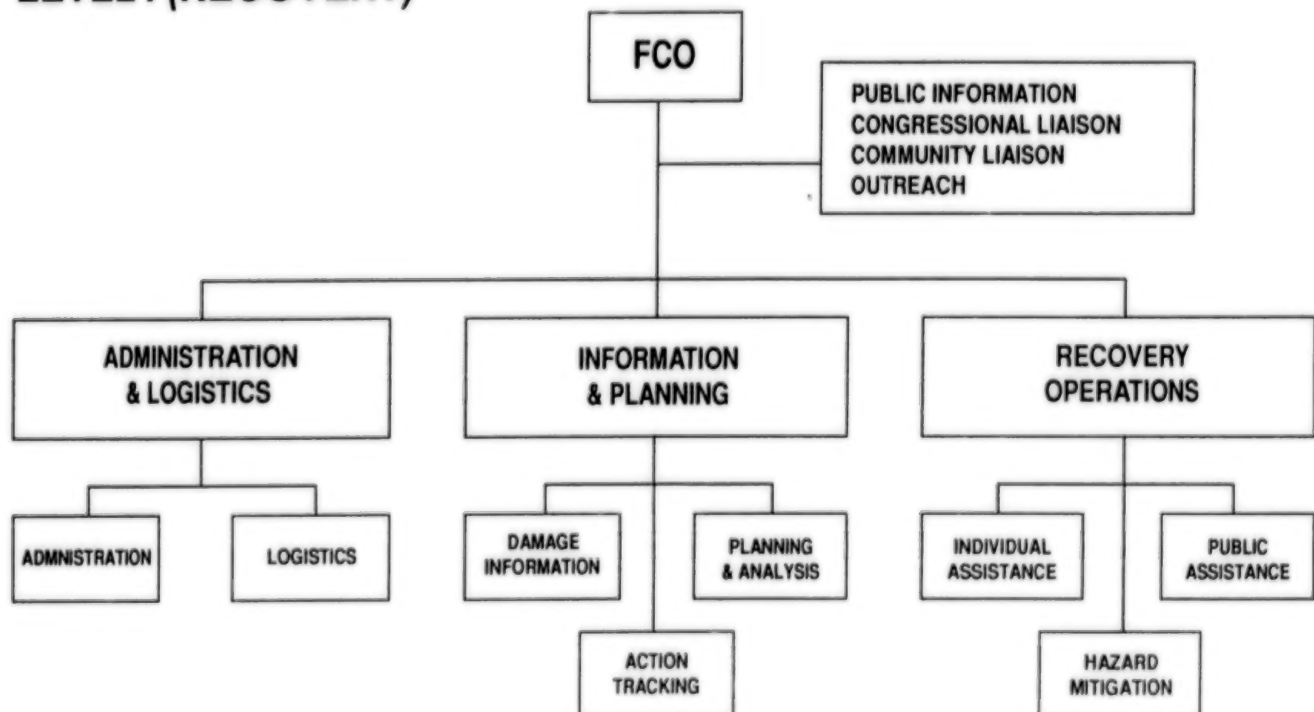


Figure 1. Proposed organizational prototype for a typical recovery operation in a small disaster.

staff members provide an official source of information regarding the incident and the status of federal actions.

Three major operating components would report directly to the federal coordinating officer: Administration and Logistics, Information and Planning, and Recovery Operations.

- Administration and Logistics covers the administrative services, fiscal services, computer support, communications, and resource support required for operation of the disaster field office.
- Information and Planning covers the collection, processing, and dissemination of damage information; the development of operational plans; and the tracking of major actions of agencies involved in recovery operations.
- Recovery Operations encompasses the three major FEMA recovery program areas: individual assistance, public assistance, and hazard mitigation.

Figure 2 shows the same basic organizational structure expanded somewhat for a near-catastrophic situation, such as Hurricane Hugo or the Loma Prieta Earthquake, where because of the magnitude of the disaster the federal government would be involved in limited response operations along with the full array of recovery

activities. The Administration and Logistics component is augmented. Emergency Support Functions are activated, if needed, to provide Communications as well as Resource Support. Under Information and Planning, the Damage Information function would be activated. Complete and reliable damage information is essential in the early stages of a disaster in order to rush resources to areas of greatest need. The Operations component is also now subdivided into both response and recovery operations. Emergency support functions like health and medical services and mass care would be activated as needed.

Figure 3 illustrates the organizational structure for a catastrophic disaster that would demand full response and recovery operations. On implementing the plan federal activity would be formally organized under all eleven emergency support functions. Response Operations would now be separated from Recovery Operations to accommodate the expanded federal role in response. In addition, emergency support functions for transportation, construction management, firefighting, mass care, health and medical services, urban search and rescue, hazardous materials, and food would be activated.

Streamlining the organizational structure of the disaster field office is only one of many changes FEMA is making based on experience gained from the Hurricane Hugo and Loma Prieta Earthquake disasters. This year

## LEVEL II (PARTIAL RESPONSE & RECOVERY)

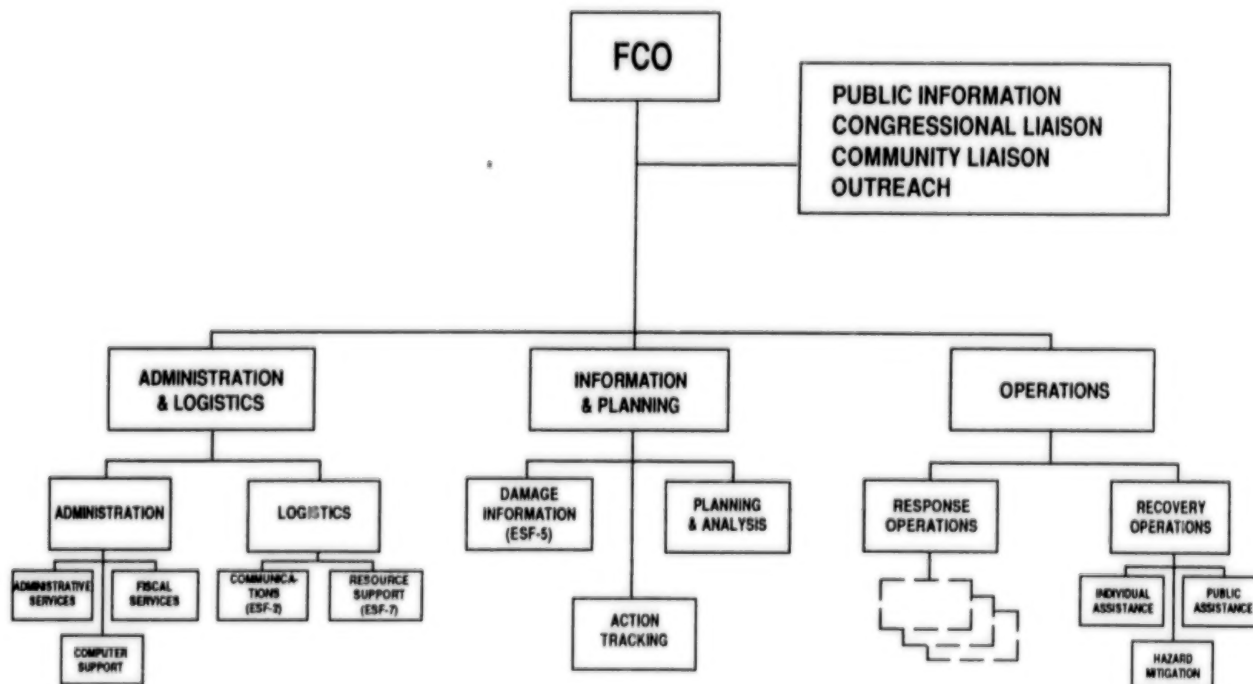


Figure 2. Proposed organizational prototype for a typical recovery operation in a near-catastrophic disaster, such as Hurricane Hugo.

the agency is also making major revisions to the Earthquake Plan itself, including:

- Clarifying federal policy, roles, and responsibilities.
- Integrating energy, water, and law enforcement functions into the plan.
- Addressing the problem of pre-positioning critical resources for immediate deployment to a disaster site.
- Pre-identifying staging areas and addressing staging-area management problems.
- Refining procedures for deploying an inter-agency advance team to assess a situation and initiate response immediately following the occurrence of a disaster.
- Developing policy and procedures for accepting, stockpiling, and distributing domestic and international donations.
- Adapting the plan to cover other catastrophic natural disasters such as hurricanes.

How credible is this federal catastrophic earthquake response planning?

Short of a catastrophic event itself, only a rigorous schedule of exercising can reliably test planning. To assure that our earthquake planning will prepare government to respond effectively, FEMA has developed an interagency earthquake response exercise strategy that

lays out over the next five years an integrated approach to improve federal and state response capabilities through workshops, seminars, and exercises. The strategy is based on a building-block approach, starting small with seminars and workshops and then advancing to more sophisticated tabletop and full-function exercises. The purpose of the seminars, workshops, and exercises is to test procedures and relationships as well as to evaluate actual response capability.

RESPONSE 89, the largest earthquake exercise held to date, involved some 600 federal and state participants at a simulated disaster field office in Sacramento, California. It provided a unique opportunity to test the adequacy of existing national, regional, and state response plans, procedures and structures to support a coordinated response.

The RESPONSE '89 scenario was based on a hypothetical—but all too possible—nightmare in the aftermath of a catastrophic earthquake on the Hayward Fault. It enacted a situation in which, suddenly, without warning the Hayward fault gives way along its entire 62-mile length. Instead of lasting a few seconds like many California tremors, the shaking continues for over 25 seconds. Within 20 miles of the fault there is major damage to buildings, utility lifelines and distribution systems, and transportation routes. The primary impact area covers nine counties.

### LEVEL III (FULL RESPONSE & RECOVERY)

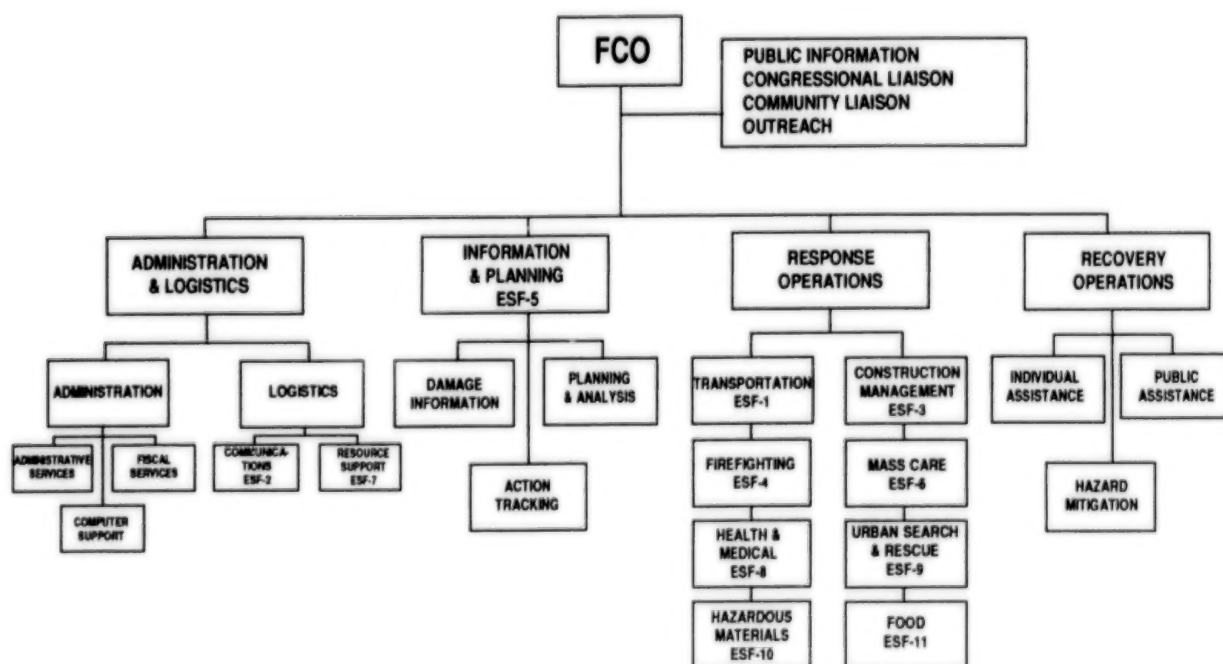


Figure 3. Proposed organizational prototype for a typical recovery operation in a catastrophic disaster.

Close to the fault, the damage is severe. On filled ground around the Bay margins, there are ground failures and landslides due to liquefaction that disrupt and deny the use of highways, railroads, airport runways, and some utility pipelines.

Fires have broken out throughout the urban areas, some of them fueled by earthquake-induced mixtures of hazardous chemicals. Within a few moments following the earthquake the entire San Francisco Bay area has been transformed into a surreal, chaotic jumble. A major concern is the unknown number of people trapped in collapsed structures throughout the area. As survivors, dazed and confused themselves, dig through the wreckage to rescue the trapped and injured, local fire, rescue, and police units are trying desperately to reorganize and respond to an overwhelming number of problems and pleas for help. Amidst the chaos even a preliminary estimate reveals that casualties number in the tens of thousands; hospitals are damaged; bridges and airports are unusable; lack of power has crippled mass transit, sewage treatment plants, gas, telephone and electric services; and hundreds of fires are raging. Although just an exercise, this scenario could turn into an all-too-possible reality for hundreds of thousands of Americans—and the emergency services and management professionals charged with their safety.

The FEMA exercise schedule also reflects that the earthquake risk is not confined just to California.

- In July of 1990, FEMA sponsored Exercise RESPONSE 90 in Salt Lake City. This joint federal/state table-top exercise simulated a 7.5 earthquake along the Wasatch Fault in Northern Utah.
- 1991 will see a joint federal/state functional table-top exercise based on an 8.5 earthquake with an epicenter in the Puget Sound area of the state of Washington.
- A table-top exercise in 1992 is planned for the Central U. S.
- In 1993, FEMA will follow-up on this year's table-top exercise with a full-function exercise based on a Wasatch Fault scenario.
- 1994's exercise will be a simulated earthquake along the San Andreas Fault in the Los Angeles area.

In addition to joint federal/state exercises sponsored by FEMA, individual emergency support function teams are being encouraged to hold their own seminars, workshops, and exercises. A least two primary agencies are conducting their own exercises. The Environmental Protection Agency sponsored "CAL QUAKE 90" in September 1990 to test the hazardous materials emergency support function in FEMA Region XI (California, Nevada, Arizona and Hawaii). The Public Health Ser-

vice and other agencies involved in the National Disaster Medical System (NDMS) held a test of this system (NDMS-90) in October 1990, with a Central U. S. focus.

Exercises are not the only way to test the effectiveness of planning. Any disaster inevitably tests emergency plans, and 1989 provided FEMA with two extraordinary events, Hurricane Hugo and the Loma Prieta Earthquake. These disasters provided a number of important lessons:

- First and foremost was reinforcement of the long-held view that planning, training, and exercising do reduce loss of life. Although the Hurricane Hugo disaster was among the costliest in U. S. disaster history, fatalities were surprisingly low. In large part this was attributable in large part to the effectiveness of hurricane preparedness evacuation planning. For example, a FEMA-funded hurricane evacuation study for the State of South Carolina was implemented by Governor Campbell before Hurricane Hugo struck. About 250,000 people were successfully evacuated from hazardous South Carolina coastal areas.
- Adoption of seismic design and construction standards pays off. Facilities built to modern seismic codes received little damage during the Loma Prieta earthquake. Similarly, Hurricane Hugo evidenced that newer coastal structures built to meet floodplain management standards suffered less damage than structures that were not.
- Hugo showed that many state and local officials outside the emergency management community are not aware of federal disaster assistance programs. This is a serious problem since these officials are key decision makers in the wake of any disaster.
- Confusion arose regarding federal roles and responsibilities—particularly those of the military and National Guard. These need to be clarified to achieve an optimally effective federal response.
- Lack of complete and reliable damage information hindered directing resources to highest priority areas. Solving this problem may involve developing the capability to deploy advance damage assessment teams.
- Policy and procedures for dealing with unsolicited donations and offers of assistance need to be developed to assure that responders will not be inundated with unneeded goods and that necessary supplies can be effectively distributed to disaster victims.

- Staging areas need to be established and coordinated in advance to support efficient shipment and distribution of emergency resources.
- Federal loan and grant programs must be streamlined so they are less confusing to applicants.

Needless to say, planning for catastrophic earthquakes is not the only federal response plan for which FEMA has statutory responsibility. As indicated previously, we will be exploring avenues to expand this plan to specifically cover other disaster situations as well—catastrophic hurricanes, for example. In addition to FEMA's continuity of government and mobilization plan-

ning responsibilities, the agency is also charged with coordinating the Federal Radiological Emergency Response Plan and crisis surge planning to rapidly increase civil defense capabilities across the nation in the event of an international crisis buildup that could culminate in a strategic nuclear attack on the United States. The Federal Response to Catastrophic Earthquake Plan has been highlighted because it is an excellent example of the process and concept of operation that embodies the basic principles common to effective planning for a range of large-scale emergency situations that demand the combined resources of federal agencies.

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# THE UNITED STATES GOVERNMENT PROGRAM FOR INTERNATIONAL DISASTER ASSISTANCE

*Ellery Gray*

Agency for International Development  
Washington, D. C.

The Office of Foreign Disaster Assistance (OFDA) is part of the Agency for International Development (AID). We provide and coordinate U. S. disaster assistance activities throughout the world. We direct disaster relief, disaster preparedness activities, and disaster related technical assistance. Our authority comes from the Foreign Assistance Act of 1961. The chain of authority comes directly down from the President of the U. S. to the executive director of AID and then to the director of the OFDA.

We are a small organization. There are 54 people in the OFDA and approximately 50% of them are not employees of the organization itself. They are either contract employees or employed by other government organizations and on loan to the operations section of OFDA. We are the specialists in the operations area. We have someone from the Federal Communications Commission, the Forest Service, and a few other organizations. Even down in the technical area, a lot of the people who provide the technical expertise for OFDA are on loan from other governmental agencies. Thus, there is a considerable amount of coordination with many other governmental agencies on the day-to-day activities at OFDA.

For example, OFDA has a contract with the state of Virginia to provide certain emergency services. In addition, OFDA works very closely with the Federal Emergency Management Agency (FEMA) and we have been working very intently in doing various phases of planning for disaster response. We do a great deal of collaboration with the American Red Cross, particularly their international division.

What is the role of the State Department in all of this when we talk about foreign disasters? The State Department provides policy. They also provide the actual declaration of a disaster. If there is a disaster which occurs in a particular country, the declaration has to be initiated by the American ambassador in that particular country. There are however, special cases, such as when we do not have diplomatic relations with the country. There was a catastrophic earthquake in Iran and we had some difficulty in getting the disaster declaration generated. In this instance the declaration was generated through the ambassador-at-large in the State Department who has responsibility for that part of the world.

The State Department provides foreign policy guidance for us when we go into a country following a disaster. When personnel are in the country to perform disaster services, they are technically responsible to the American ambassador. The AID has missions in many countries, but they do not have missions in every country where there is an embassy. The following are some of the roles we perform where there is a U. S. AID mission:

- Support local government in making assessments of the particular disaster which has occurred.
- Provide technical expertise in health, engineering, and housing.
- Monitor all U.S. supplies coming into the country.

We have had a great deal of difficulty with this last category. There are still supplies sitting in warehouses down in Mexico City that have not been utilized following their earthquake. Armenia still has several large warehouses full of medical supplies that have not been utilized.

## OFDA CRITERIA FOR DISASTER DECLARATION

In order for OFDA to respond to a disaster the disaster must meet the following criteria:

- An event must take place.
- The event must exceed the local capability.
- The event must be appropriate for the U. S. to respond to.
- U. S. assistance must be acceptable locally.

Often times this is tied directly with the humanitarian need and the political influence which may be occurring at the particular time. In some instances, it is more politically expedient for us to respond to a much less broad scope of disaster than it would be at other times if the disaster were of tremendous proportions. Iran is a good illustration of this. We do not have diplomatic relations with that country and people are in a quandary as to how we should respond. We did know that we were going to respond in some manner and we have. Another question is, will the Iranian government accept the U. S.

donations of supplies, equipment, and whatever else we might want to put in there?

To provide part of the technical assistance response of OFDA, there is a component called the Disaster Assistance Response Team (DART). The DART will deploy to a disaster site to provide support in such areas as operations, relief planning, logistics and administration. The team will be fashioned according to need and will perform such functions as supporting local needs assessments and coordinating local and international communications with other teams. Subcomponents of the team will be attached as needed, providing technical expertise in the areas of medicine, shelter, hazardous materials, and search and rescue. The DART is OFDA's representative at a disaster site, assisting the U. S. Mission in the stricken country to:

- Conduct damage and needs assessments.
- Determine the most effective form of U. S. Government assistance.
- Help organize mission resources.
- Manage the U. S. Government disaster relief efforts in support of local efforts.

The disaster types OFDA responds to are of three general kinds, traditional natural, manmade and technological disasters. The traditional natural kind of disasters that we respond to are, hurricanes, volcanoes, floods and other forces of nature. The manmade disasters we deal with are those such as fires and civil strife. An example of a manmade disaster was the nuclear disaster which occurred in Chernobyl. We deal with technological disasters such as chemical plant disasters. Looking at these three areas of disasters, you can see we are weaving here for you a rather complex response approach. We do not intend to be all things to all people because we do have limited budget and a very limited staff. We look at those things which we can do effectively and efficiently.

The U. S. has certain resources which have been developed through our normal disaster programs in the past. We have come to the conclusion that those disaster resources need to be shared internally. Therefore, we are now beginning to utilize the same resources for domestic disasters that we have been utilizing previously for foreign disasters. This gives us a tremendous amount of leeway because with a limited staff, we can now count on agencies like FEMA and the Public Health Service to assist us in helping us further develop the capabilities of these organizations which can respond to disasters. Of course, by no stretch of the imagination will all the response units which are being developed throughout the country respond to foreign disasters. There will be a very small number of them who will do that.

We do not cover accidents such as a private sector accident. An oil spill would be an example of an accident that we would not normally cover. However, as

with everything there is always an exception. We cover natural disasters, such as, earthquakes, hurricanes, floods and volcanoes. One of the manmade disasters for which we do a tremendous amount of response for civil strife. We are involved in six separate disasters in Africa where civil strife is the predominant motivator for the disaster. We also respond to technological disasters. In the case of an oil spill, if it occurs on water and there is no immediate danger to life, then we will not respond. However, we would get involved if the oil spill occurred in a harbor, and the oil spill has created a fire, where it would now threaten homes and human lives. Thus, although we do not get involved in spills, there are certain instances where we could.

We responded to a disaster in the Soviet Union when a train crashed at Ufa. There was an explosion of a natural gas line resulting in many people getting burned. We began to get requests for assistance for treating burns from other countries. We responded as we have developed the capability of getting a burn team operational within four hours of the time the disaster has been declared.

We responded to almost 40 disasters in the first six months of Fiscal Year 1990 as illustrated in Table 1. We had an extremely busy year in 1989 and responded to over 80 disasters. These are not all catastrophic disasters nor are responses high in terms of urgency and immediacy. Some of them are slow onset disasters and we may have been working different aspects of them at different times. However, new problems may have occurred and will reopen the disaster declaration and move on forward with another activity. Some of them are small and we only respond in money. The minimum response generally is \$25,000. The ambassador in every country has a discretionary fund that is used quite frequently.

We have had a lot of inquiries lately about aircraft crashes. There has been much debate within the State Department whether or not it is appropriate for U. S. resources to be utilized in aircraft crashes on foreign soil. Although we have not completely developed a policy for this, the Lockerbie crash has certainly demonstrated that there needs to be a tremendous amount of coordination and cooperation between the federal agencies that could be involved in an operation such as that. Although the FBI was involved in Lockerbie, we were not. Again, there are exceptions. We responded to a civil aircraft crash in Poland at the request of the Polish government. The FBI went over to identify bodies in that particular aircraft crash at our request. In that instance, even though there were bodies, we were not responding to humanitarian needs other than to help identify bodies. Our hard and fast policy was again bent, simply because of the diplomatic relations and the political expediencies of the moment.

**Table 1. DISASTER DECLARATIONS BY THE OFFICE OF FOREIGN DISASTER ASSISTANCE DURING THE FIRST SIX MONTHS OF FY 1990.**

COUNTRY	DISASTER	DATE
1. Philippines	Typhoon (Dan/Sailing)	10/12/89
2. South Africa	Food Shortage	10/13/89
3. Angola	Drought	10/13/89
4. Ethiopia	Drought	10/14/89
5. Sudan	Civil Strife	10/19/89
6. Mozambique	Civil Strife	10/27/89
7. Thailand	Typhoon (Gay)	11/06/89
8. Algeria	Earthquake	11/16/89
9. El Salvador	Civil Strife	11/17/89
10. Yugoslavia	Mine Accident	11/21/89
11. Philippines	Emergency	12/04/89
12. Colombia	Emergency	12/15/89
13. Rwanda	Food Shortage	12/15/89
14. Panama	Emergency	12/21/89
15. Romania	Civil Strife	12/26/89
16. Liberia	Displaced Persons	01/16/90
17. Cote D'Ivoire	Displaced Persons	01/17/90
18. Somalia	Civil Strife	01/22/90
19. Madagascar	Cyclone	01/24/90
20. Tunisia	Floods	01/26/90
21. Indonesia	Floods/Landslides	01/29/90
22. Paraguay	Floods	02/01/90
23. Guinea	Displaced Persons	02/05/90
24. Western Samoa	Cyclone Ofa	02/05/90
25. Uganda	Epidemic	02/06/90
26. Burma	Fires	02/08/90
27. Lebanon	Civil Strife	02/13/90
28. Tuvalu	Cyclone Ofa	02/12/90
29. Tonga	Cyclone Ofa	02/14/90
30. Turkey	Accident	02/16/90
31. Indonesia	Volcanic Eruption	03/05/90
32. Tanzania	Floods	04/20/90
33. Bolivia	Drought	04/29/90
34. Grenada	Fire	05/02/90
35. India	Cyclone	05/11/90
36. Peru	Earthquake	06/04/90

We could have some serious problems down in the Caribbean with cruise boats. We are not sure how we would respond should a cruise ship catch on fire resulting in a tremendous number of casualties. There is a possibility that we would respond. If we did, we would coordinate with the Coast Guard and other maritime authorities. Another question we have is if there is an air crash with many survivors, we realize many Caribbean countries, particularly the islands, would be immediately overwhelmed with their ability to handle the medical casualties. Currently we do have a contingency but the policy has not been clearly set up yet as to whether or not we would be involved. The State Department is now working with the major airlines and we expect a policy to be developed.

As with FEMA, disaster response is a local government responsibility. We try, wherever possible, to work with the local government's needs and desires to make things happen. We work very closely with many international organizations, coordinating activities, and with private voluntarily groups. Frequently, this is where a lot of the activity really occurs. We will attempt to help private voluntary groups get certain commodities and items and sometimes get people into various countries to respond to the disaster. It often comes back to money. The U. S. as a whole, is a very warm, giving country and people want to respond personally to disasters. However, it is very difficult for us, through the governmental process, to be able to respond in the magnitude in which our country would like to respond at different times. We have an annual budget of \$28 million to cover an entire world with some major operations. Consequently, it is very important for the private sector of the U. S. to get involved and be able to process their donations and their resources. We provide relief assistance based upon a substantial assessment of the patient's needs.

We are trying to gear our disaster response to programs that are going to be beneficial to that country in the longer term. For example, our burn response is now geared towards leaving some professional expertise and philosophy behind. Once our personnel are involved in a short term disaster response, we will attempt to work through the private voluntary groups and other organizations to get preparedness resources into that particular country. It may be after the fact. For instance, our burn response teams went to the Soviet Union. Then we had several teams go back to the Soviet Union and began to have substantial exchanges of professional ideas and concepts with the Soviets. This has happened in other countries with other teams. We are using that developmental policy to help them to be able to cope better next time.

We respond only to the most urgent lifesaving needs. We do not respond to needs of people requesting, for example, to have either houses rebuilt or businesses reestablished. OFDA can only respond to the immediate lifesaving and humanitarian needs of the victims.

There are times when relief and technical assistance can be reimbursable particularly in the area of technological problems. We sent people out with the Environmental Protection Agency to clean up chemical problems which has turned out to be an extremely expensive operation. We do have a lot of expertise and ability but we do not have unlimited funding to help foreign countries with these kinds of problems. We can send technical expertise, arrange for consultants and contractors to come over and do the work, but we cannot pay for it. If these countries are willing to pay for it, then we will make all the arrangements. Sometimes the coun-

tries will indicate their willingness to pay. Then we try to have supplies released when we get them out there. However, we try to get the relief supplies locally. When there was the earthquake in Iran there was a need for a lot of hand tools to be used in the search and rescue efforts. We will not buy hand tools in the U. S. and fly them on over because it is very expensive to fly those items over. We will try to purchase the hand tools either within the country itself or as close to that particular location of the disaster as possible to cut down on transportation costs and also to get a quick response time.

We have four stockpiles of supplies at the present time located in strategic areas. The stockpiles are in Panama, Italy, Singapore and in Maryland in the U. S. Those stockpiles consist of the normal items needed in an immediate response such as blankets, tents, water containers, water purification units, and the basic things that can cover a wide multitude of disaster needs. OFDA tries to respond with some kind of tangible item, technical expertise, within 24 hours. There have been occasional times when we are not able to do that but that is our goal. We have been pretty fortunate in being able to meet that deadline on most disasters.

As discussed previously, donating relief supplies is a tremendous problem. Hurricane Hugo certainly pointed that out. Hurricane Gilbert was another excellent example of a lot of supplies coming in. If you can imagine the wide array of supplies that were received on the docks in Miami and also on the docks in the Virgin Islands. People will put anything into a box and send it off. Some boxes we have not opened yet and may not be. People are well-meaning and want to give whatever they can. Some people only can give clothing. Unfortunately, in many cases, the clothing is not new and some of it was in very bad repair. Another example is when canned goods were provided some people took out whatever they had on their shelves. People sent canned goods, such as dill pickles, and people would not eat them. Canned goods are very heavy and expensive to transport so we do not want inappropriate items. Thus, the U. S. government will not transport donated supplies.

We reimburse the Department of Defense whenever we utilize their aircraft so we are only going to put on supplies and equipment that are actually needed for lifesaving purposes at the time. We are going to use that airspace very diligently. Thus, when people indicate they have a ton of supplies here, and three tons over here and request transportation, we refuse. We are, however, very successful in arranging for other organizations to transport the supplies. Many times the airlines will provide free airspace. For example, the Rumanian airline provided free airspace for donated items going over to Romania. When assistance was requested in the Caribbean, the airlines were very helpful in providing space.

The shipping companies out of Miami were particularly helpful in making large containers available for people to put supplies and equipment in for shipment. These might not be needed immediately but could be utilized in a couple of weeks.

The OFDA has been very involved in planning, preparedness, and mitigation for many years. In the last five years OFDA has moved at a rather rapid pace. We have begun the transition of being an organization which was oriented to coordinating activities into an organization which is much more responsive. We do have teams which can get out onto the ground and actually carry out operations.

Hugo, 30 years ago, would have probably gone up the coast and gotten on the television very briefly, received a little bit on the radio occasionally, but it would not have created the number of problems that we had simply because we now have larger concentrations of people. When you have larger concentrations of people, the opportunity for a natural disaster to occur multiplies. We are predicting that the number of disasters will continue to increase throughout the years because the populations are continuing to expand. In the process of expanding populations, people are now finding it difficult to have good land, good places to build homes, and they begin to live in marginal areas.

Bangladesh is an example of this. The countryside is devoid of all timber. The only really fertile land in that country is down in the delta area, at sea level. If there is any kind of a storm at all coming into that delta, it will be inundated by water. There are now several million people living on that delta. Although we have all of these great, wonderful warning systems, they will not leave their land because this land is constantly shifting and changing. They have no title to it and are basically squatters there. Whatever you try to do, you are not going to move these people off this land. They are going to try to stay as long as they possibly can because it is all they have. Therefore, you have the opportunity to have a tremendously catastrophic disaster if a large storm comes into this area. I am not talking about 60 or 70 people being killed but 300,00 to 500,000 people being killed. We have seen these large casualties in Armenia and Iran when earthquakes of great magnitude hit highly populated areas along the coast or in mountain ranges. We do not really know how many people are really there, because these small villages are isolated in mountain ranges.

When the earthquake hit Armenia the children were in school. All of the schools were built of the same design and collapsed with the same frequency. A third of the next generation was wiped out in those areas when struck by this earthquake. Armenia, as you know, is right next door to Iran and there are several major faults in this area. In fact, three of them come together. This

area, therefore, is earthquake prone. In the Armenian earthquake, the official toll was 25,000 but the actual toll was well over 50,000. There were many people that we could not even get to. They were buried under the rubble and it would have been impossible to reach them.

What were some of the lessons we learned? We learned that telephones, all electronic equipment, was out of order. We also learned that personnel and equipment did not necessarily get to where it needed to go when it needed to be there. Transportation systems were completely disrupted. We knew we were going to have a lot of problems with equipment and supplies. We learned many things from the Armenian earthquake and we have put what we learned into our planning.

One area of planning has been how we set up our response teams. We regard to the medical response area we know that in order to be effective we have got to get medical care to these people within the first 48 hours, otherwise we are wasting our time. Those are the golden hours for people in earthquakes. This is not only for earthquakes but is basically for all other medical and

health conditions. If you cannot be there quickly, then your immediate response teams are not going to be that helpful. We utilize whatever means we can, either civilian or military aircraft to get our teams in. I have specific medical teams that are set up. There is a team that is a medical adjunct to the search and rescue people. That team is ready to leave within four hours of the time we notify them. They are self-contained and can treat 100 patients. They have dialysis units, intensive care units and water and sanitation epidemiology, and we have other specialized units can be tailored to a specific disaster.

To summarize we have an international response that is well-structured in terms of policy and procedures. We are involved in mitigation, preparedness, and recovery to some degree. We are in the transitional area of moving into disaster operational responses in specifically defined areas. We have many other areas that we get into too, particularly, famine, drought, and nutritional problems. Those, however, are on a much wider scale and longer term disasters.

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# VOLUNTEER ORGANIZATIONS IN EMERGENCY SITUATIONS

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This paper describes nonprofit, volunteer agencies and their role in disaster response. The first part of this paper will focus on volunteer organizations primarily in the U. S. The second part of this paper will focus on the American Red Cross and what we do with emphasis on domestic response in the U. S. The last part of this paper will provide some information on the International Red Cross.

## OVERVIEW OF AMERICAN VOLUNTEER ORGANIZATIONS

As you are probably aware, the U. S. is somewhat unique in the world because of the multitude of volunteer organizations that we have. This has been commented on since the founding of our country. Volunteer organizations have a long history in the U. S. In terms of disaster relief, this is equally the case. In the beginning or during the early days of our country right up until the 1950's the predominant response to disasters in the U. S. were by volunteer organizations. It was simply a matter of people on the local level, local community groups, organizations, getting together when a disaster hit their community and providing relief to their fellow citizens. This has carried forward all through our history and there is still a very strong component of disaster response, disaster planning, disaster preparedness in the U. S.

Volunteer organizations share common characteristics. Volunteer organizations are predominantly service focused which means they provide direct human service assistance to disaster victims. There is an element of preparedness, an element of response, but basically what they are interested in is providing some type of service, some type of assistance to disaster victims.

One important characteristic of volunteer organizations is that they are community based. This means that in most communities there is either one or two of these agencies, and the people that belong to those agencies are community members, community residents. Thus, there is the local unit in these organizations. While there is the local unit, there is also a national component. If that local unit, for example, a church group, is confronted with a disaster that is beyond the capability of their resources, that unit has the ability to go to its' national organization and request assistance. However,

again the point to emphasize is that there is the local unit or part of the community, the ongoing activity of the local community.

Another common characteristic of the volunteer organization and is that they employ very few professional staff. Most of the services and activities are provided by volunteers, and again, the volunteers are from the local level or regional volunteers from surrounding communities. Let me emphasize that the important point is that they are predominantly volunteers.

These organizations also have the ability to have program flexibility. By this I mean these organizations and agencies can quickly change what their service package is. They do not need to go through enabling legislation. They do not need to go through a whole series of authorities in order to decide that they are going to provide a new service in a community or they are going to provide that service a little bit differently. They do present a certain standard set of programs and assistance in a community. However, they do have the ability that based on the need or requirements of that community they can change quickly and provide that new service if they are capable financially and able to do it.

Volunteer organizations have as a major characteristic their independent nature. This means they are willing to work with other organizations, and to work with the local, state and federal government. However, they are very guarded in terms of their independence. They want to maintain their independence and also their separate identity. This is extremely important to them. All of these volunteer organizations have limited resources. The vast majority of these organizations are supported by volunteer contributions either through general fund drives or through dues or membership fees from their members. As a result, they have to be very particular and very careful in terms of focusing their resources and services. They cannot be all things to all people. Actually, this is a characteristic that I believe is common with many agencies both in the public and the private sector.

The final characteristic I would like to discuss is the recognition that many of the volunteer organizations have an uneven service distribution nationwide. By this I mean that many of the organizations may be particularly strong in one area of the country and almost nonexistent in another area of the country. As a result, the frequency of service, the type of service, really depends

on the strength in that community. In certain areas of the U. S., particularly with religious-based organizations, they are very strong and very developed, and have a great deal of resources and manpower. In other areas of the country, however, this same religious-based organization may have a very small constituency. Consequently, they are not as active and can not provide the same level of service.

There are a number of different agencies that provide assistance. A number of them are religiously based but religion does not have an impact in terms of the assistance they provide the people. It is not a criteria for assisting people. They do it out of a motivation to perform good deeds for people in general. The best advice I can provide to the people that are interested in contacting or finding out just what organizations exist in their community, is to contact your local Red Cross chapter. We maintain liaison with these agencies. On the national level there is the National Volunteer Agencies Active in Disasters (NVOADS). The Red Cross is the largest of these organizations and does provide support to this confederation of private volunteer organizations. In some communities you will find several of these agencies and they can be very effective in dealing with local disasters. They should be a part of your disaster preparedness and response planning. Many of these organizations are also involved in foreign disaster relief.

### **AMERICAN RED CROSS**

The status of the Red Cross in the U. S. is a little bit unique. We were chartered by Congress and our status is really that of a quasi-federal agency or as an instrumentality of the federal government. This means we are chartered by Congress to provide a program of national and international volunteer disaster relief, however, we receive no funding from Congress. The Red Cross is expected to generate its own funding.

We are governed by a board of 50 volunteers. Eight of them are appointed by the President of the U. S. The others are appointed through a number of appointment processes. So, while we have a Congressional charter, we do stand as an independent organization. This was done for a number of reasons. The Red Cross holds a number of responsibilities and obligations in carrying out certain tasks for the federal government as a part of the general Red Cross movement. There are also implications for the Geneva Conventions. As a result, the independence of the organization was assured.

We do have a national headquarters in Washington, D. C., that is primarily responsible for policy, direction, and oversight. We also have three operational headquarters. The eastern part of the U. S. is covered by the operational headquarters in Alexandria, Virginia. The

operational headquarters in St. Louis, Missouri, covers the central part of the U. S. Lastly, the operational headquarters in Burlingame, California, outside of San Francisco, covers the western part of the U. S. and the Pacific Trust territories. Our operational headquarters functions much like a federal regional office in terms of providing support and assistance to our Red Cross chapters. We have roughly 2,700 Red Cross chapters throughout the U. S.

Our definition of disaster is very broad. It goes anywhere from a one family residential fire in a rural community up to a situation like Hurricane Hugo or the northern California earthquake. We do have some exceptions though in our disaster definition. One is an act of war and how we respond. A second is economic maladjustment, which is just another word for plant closings, recessions, and depressions. Basically, our definition of disaster involves an act which causes the sudden dislocation of people, disruption of their normal life.

In terms of our method of operation, we follow the same pattern as described by Peterson (1992) for the Federal Emergency Management Agency (FEMA) and by Gray (1992) for the Office of Foreign Disaster Assistance (OFDA). That is, the local Red Cross chapter is responsible for responding to disaster relief within the local community, as with the local government. If the disaster is beyond the scope and the resources of the local chapter, then the national sector comes into play and that is through our operations headquarters. We have available for them funding and materials if needed.

We maintain a system of 10 warehouses in the U. S. with disaster supplies such as cots, blankets, comfort kits, feeding equipment, and food and beverage containers. We have a fleet of 240 disaster vehicles to provide vehicle distribution support. These are vehicles such as 48-foot trailers down to specially designed response vehicles. These vehicles can be sent to the area to provide assistance for the local chapter. In addition, we maintain what we call a disaster human resource system. This is a data base of about 4,100 individuals throughout the U. S. that are trained technicians to respond to disasters. Another role of the chapter is it works closely with the other nonprofit organizations or volunteer organizations. The chapter also works very closely with the local emergency managers to develop the community response plan. Thus, the sequence would be to work with the chapters at the local level, the state would work closely with the state emergency management people, and on the national sector, we would work very closely with agencies such as OFDA and FEMA.

The Red Cross is recognized in all of the federal legislation that has to deal with the disaster response. The role of the Red Cross was recognized in the 1974 Disaster Relief Act and also in the Stanford Act of 1988.

We work very closely with FEMA at the national level and particularly with the National Earthquake Response Plan. The Red Cross is a part of that plan with designated responsibilities for mass care which is basically the sheltering and feeding of individuals.

We provide what we term a service package which can be broken down to three elements. The first is the mass care element. This is providing sheltering and mass feeding for disaster victims and also emergency workers either before, during, or immediately following the onset of the disaster. A component of mass care involves bulk distribution. This is accomplished through the 10 warehouses that I discussed previously. We have items that our experience indicates are needed quickly in local domestic disasters. These items can be cots, blankets, and comfort kits, which are basically personal hygiene. There are also items such as clean-up kits that we use quite a bit for hurricanes and floods. These clean-up kits contain items such as shovels, brooms and disinfectant. People can then go into their homes after the floodwaters have receded and clean their homes and try to get back into them.

The second element is what we call emergency assistance, which, in essence, is case work. Case workers sit down with the individual disaster-affected families and try to determine what they need right now, right at that minute, to begin to try to get their lives back in order. The assistance we provide is a direct disbursement. We give them an item called a disbursing order which basically is a check. They can take that to the vendor of their choice and buy the items that they need. The eligibility criteria is very simple. Individuals qualify if they reside within the disaster affected and can provide some type of proof that their home has been damaged or effected. Then assistance is given the day of the interview. The type of emergency assistance we provide through this procedure is food and clothing to people who have lost either food, clothing or both. Also, we can provide temporary housing if someone's home is destroyed or severely damaged and they are unable to locate a rental unit in the community. We will provide assistance to pay for that initial rent and also the security deposits so at least they have a place to stay so they can begin to get their homes repaired or replaced.

Another component we provide for is emergency minor home repairs. This provides assistance, in the form of a disbursement to the family so they can make their homes safe, secure, and sanitary. In some situations it could simply be replacing some of the floorboards that are warped because of a flood. In other instances it could be replacing windows that have been blown out. Simply stated, quick repairs that can be made to a home so that home can be livable again by the family. Another area of service we provide for is household furnishings. These

would be items such as beds, bedding, sheets, pillowcases, tables and chairs, dinette sets, pots and pans. Basically, items that a family needs to begin to live again as a family. In many cases, people's homes are destroyed and they are able to find a rental unit in the community. However, they need the basic furniture to move in and get started and we can provide that type of assistance.

We also provide medical assistance. We do not provide emergency treatment for disaster victims. We do, however, assist people that have been injured as a direct result of a disaster and require emergency medical assistance but do not have the means to have pay for those bills. Another major area in medical assistance involves replacing needed items. This could be helping them (or paying for them) to replace prescription drugs that were lost because of the disaster. Also, we provide assistance with such items as false teeth, eyeglasses, hearing aids that may have been lost as a direct result of disaster. In some cases, especially when you have quick evacuations, people tend to leave these items behind. These are essential items.

The third element that we provide under emergency assistance would be occupational supplies and equipment. We sit down with a family and determine what their occupation is and what tools they would need to work. For example, a nurse would need a uniform. It could be trades tools, such as a plumber would need plumbing tools replaced to resume working again. In the case of coal miners they would need certain boots and helmets that were lost as the direct result of the disaster and would need those items to get back to work. Our intent is to provide this assistance on an emergency basis and deal with the individual families. We try to get them back into the rhythm of their normal family life prior to the disaster. Again, it is provided on an emergency basis.

How do we integrate differently than the government. Particularly, what does the state and federal governments do for disaster victims? We view the state and federal governments as being responsible for the safety and welfare of the community. We see the governments filling those responsibilities such as evacuations, warnings, and security within effected areas. The Red Cross and the other private or nonprofit agencies look after the needs of the disaster victims. We work with the federal government, such as FEMA, and the Small Business Administration. We also work with the state government through programs such as the Individual Family Grant Programs which is administered by many of the states. We see our role primarily at providing what emergency assistance is needed by the disaster victims, while the federal government, through the state grants, gear up to provide for the long-term recovery of the disaster victim. So, our role is designed to be quick and short term,

to provide what is needed until substantial federal assistance becomes available to the disaster victims.

One final area to describe for additional assistance is the Family Grant Program. This is a program we thought we were going to get out of and actually did back in the 1970's with the introduction of federal assistance in the Family Grant Program. However, we have been increasingly doing more and more of what can be termed additional assistance. This is provided after either a large or small disaster. As an example, a family has taken advantage of all the assistance that is available to them but still has disaster needs, directly related disaster needs. We will then sit down and work with the family to see if we can address those needs. In the case of a large disaster, such as a presidentially declared disaster and after the federal assistance has been disbursed, we may find individuals that still have needs that are beyond the maximum available from federal assistance. This would be a long-term case work type of activity and we try to address those needs. A majority of those cases in which we provide this type of assistance deals with building and repair. For example, people with fixed limited incomes that still need assistance for repairing their homes. The second type would be medical assistance for people that have substantial medical bills or require long-term medical treatment over several years and do not have the resources to do that.

To summarize, we work closely with the local emergency managers on city, county and state in planning and preparing for major disasters. We also work very closely with FEMA in planning for major disasters. Our intent is not to duplicate assistances being provided by other people, but rather to see if there are services we can provide beyond what is being provided by others.

## **INTERNATIONAL RED CROSS**

Each country in the world has its' separate Red Cross society. In some cases, as in the Islamic countries, they are called Red Crescents because of the religious connotations of a cross in Islam. But, the American Red Cross, along with about 140 other Red Cross societies, belongs to an organization called the League of Red Cross Societies. The headquarters is in Geneva along with the International Committee of the Red Cross. When a foreign disaster occurs, as an example, the recent earthquake in Iran, the member society, in this case, the Red Crescent of Iran, would make a request to the League of Red Cross Societies in Geneva and request supplies, equipment, personnel, etc. It is through the League of Red Cross Societies that they sort out who can best provide the items that may be needed.

Many European Red Cross societies are very medically oriented and have a large number of medical care

personnel available such as physicians, nurses and physical therapists. In other countries, such as the U. S., we provide assistance more in terms of materials for mass care. Therefore, it is up to the League of Red Cross Societies to determine what is needed by the country with the disaster and then to approach the individual societies and to request that they provide certain support. In many cases the League of Red Cross Societies will come to the American Red Cross and ask for money. Then they can purchase the materials closer to the disaster, rather than to buy things in the U. S. and go through the logistics of shipping items from the U. S. over to foreign countries. In other situations a request is made to the American Red Cross to send over personnel. For example, in the case of Armenia we sent over some physical therapists and physicians, also some special nurses. We have a system similar to OFDA in which we have individuals that have had a particular type of training and we can make them available for foreign assignments.

The length of our assignments vary a great deal as it depends on the situation. We can have personnel assigned for three months, while in some cases, we have had people overseas for two years. In many cases, however, they go over not as a representative of the American Red Cross but as a representative of the League of the Red Cross Societies. There is a subtle distinction made in many foreign countries that there is a big difference between someone from the U. S. versus someone from the League of Red Cross Societies.

One problem we experience is how to respond to requests from individuals or organizations that want to provide assistance to foreign countries that need disaster assistance. Some individuals or organizations want to send supplies and/or equipment to that country and will arrange for shipment of these materials and request our assistance. We are very reluctant to do that. In many instances OFDA will be approached by people who want to ship supplies to foreign countries. We will not provide assistance with shipment unless the supplies are specifically requested by either the government of the country or by the Red Cross society or Red Crescent society in that country. In our experience we find many well intentioned individuals want to provide assistance and ship supplies but frequently the assistance and supplies are either not requested or appropriate. Further, these supplies that are not needed tend to further overwhelm the generally already overburdened and damaged distribution system in that country.

There are also difficulties in getting supplies distributed inside the country once they arrive. This is particularly true in third world countries. We have experienced significant problems such as this in some of the countries in Africa and in some of the other underdevel-

oped countries. We have to be extremely careful in terms of what we ship and the logistics that need to be set up in the country to handle it. Will the shipped supplies be distributed to the individuals for which they are intended?

In summary, nonprofit, volunteer agencies in the community have an important role. The Red Cross, together with many other agencies and organizations are an available resource. They are particularly useful in emergency management and can be responsible for putting together community or county emergency response plans. They are willing to work with you and should be used. They should be put into your equation in terms of responding to disasters.

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# EARTHQUAKE FORECASTING AND INFORMATION SERVICES

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Throughout the history of mankind, major earthquakes have caused the deaths of hundreds of thousands of people and the loss of billions of property. With increasing world population and the growing size of large cities, the vulnerability of people and their property to earthquakes is becoming greater each day. By the year 2000, there will be more than 100 cities with populations greater than two million people. Forty percent of these cities are located within 200 km of a tectonic plate boundary or an earthquake that caused damage in the past. Within the next 10 years 290 million "supercity" dwellers, 80% of them in developing nations, will live in a region of seismic risk. Within the next 45 years, given current rate of growth, the global population at risk will double (Billham 1988).

The International Decade of Natural Disaster Reduction comes at a time when many nations are faced with the inevitability of natural disasters, and the harsh economic realities of restricted economic resources (Advisory Committee on the International Decade for Natural Hazard Reduction 1987). The prudent development of disaster mitigation and reduction programs for specific locations, within socially beneficial time frames requires an understanding of when and where natural disasters are to occur. Once disasters do occur, rapid communication and response are necessary to reduce loss of life and property.

In the past 30 years, great strides have been made in the fields of seismology and geophysics towards understanding the nature of large and great earthquake occurrence along simple plate boundaries. More recently, these advances have lead to the development of long-term (that is, decades) earthquake forecasts for specific fault zones. Coupled with these theoretical advances there has been an improvement in the collection, interpretation, and distribution of earthquake data. Rapid determinations of earthquake location and size have enhanced the effectiveness of emergency response in both the United States and the world.

## EARTHQUAKE PREDICTIONS AND FORECASTS

An earthquake prediction is a precise statement of the time of occurrence, location, and size or mag-

nitude of a future significant event. The time for a prediction is usually less than 10 years. Statements that span longer time frames (that is, decades) are termed earthquake forecasts. Within the United States, the Director of the U. S. Geological Survey is responsible for deciding when and/or whether to issue predictions or other information regarding the potential for the occurrence of a future significant earthquake. The first offices to be advised, following the Director's decision to issue a prediction or advisory, are the

Secretary of Interior, the Director of the Federal Emergency Management Agency (FEMA), and the governor(s) of the state(s) affected by the Director's statement.

The National Earthquake Prediction Evaluation Council was established to advise the Director of the completeness and scientific validity of data used for specific earthquake predictions. The Council is composed of both Federal and non-Federal representatives who are experts in scientific disciplines related to earthquake prediction. Within the last few years, the National Earthquake Prediction Council has convened working groups to evaluate the earthquake threat in California. The 30-year earthquake forecast for the San Andreas fault system (Figure 1) represents the first federally and state sanctioned earthquake forecast. While this report represents the current state of knowledge about earthquakes in California, it will be periodically revised as more information becomes available. Currently, it is estimated that the probability for an earthquake of magnitude greater than 7.5 in southern California is at the 60% level during the next 30 years (Working Group on California Earthquake Probabilities 1988). While the occurrence of the October 17, 1989, Loma Prieta earthquake served to heighten earthquake awareness on a national level, it did not reduce the potential for future events in the San Francisco Bay area (Figure 2). Current estimates indicate a 0.67 chance for an event of magnitude greater than 7 during the next 30 years in the San Francisco Bay region (Working Group on California Earthquake Probabilities 1990). On a more immediate time frame, the Parkfield Earthquake Prediction Experiment, along the San Andreas fault in central California (Figure 1), is designed to monitor the preparation process of a magnitude 6 earthquake which is expected

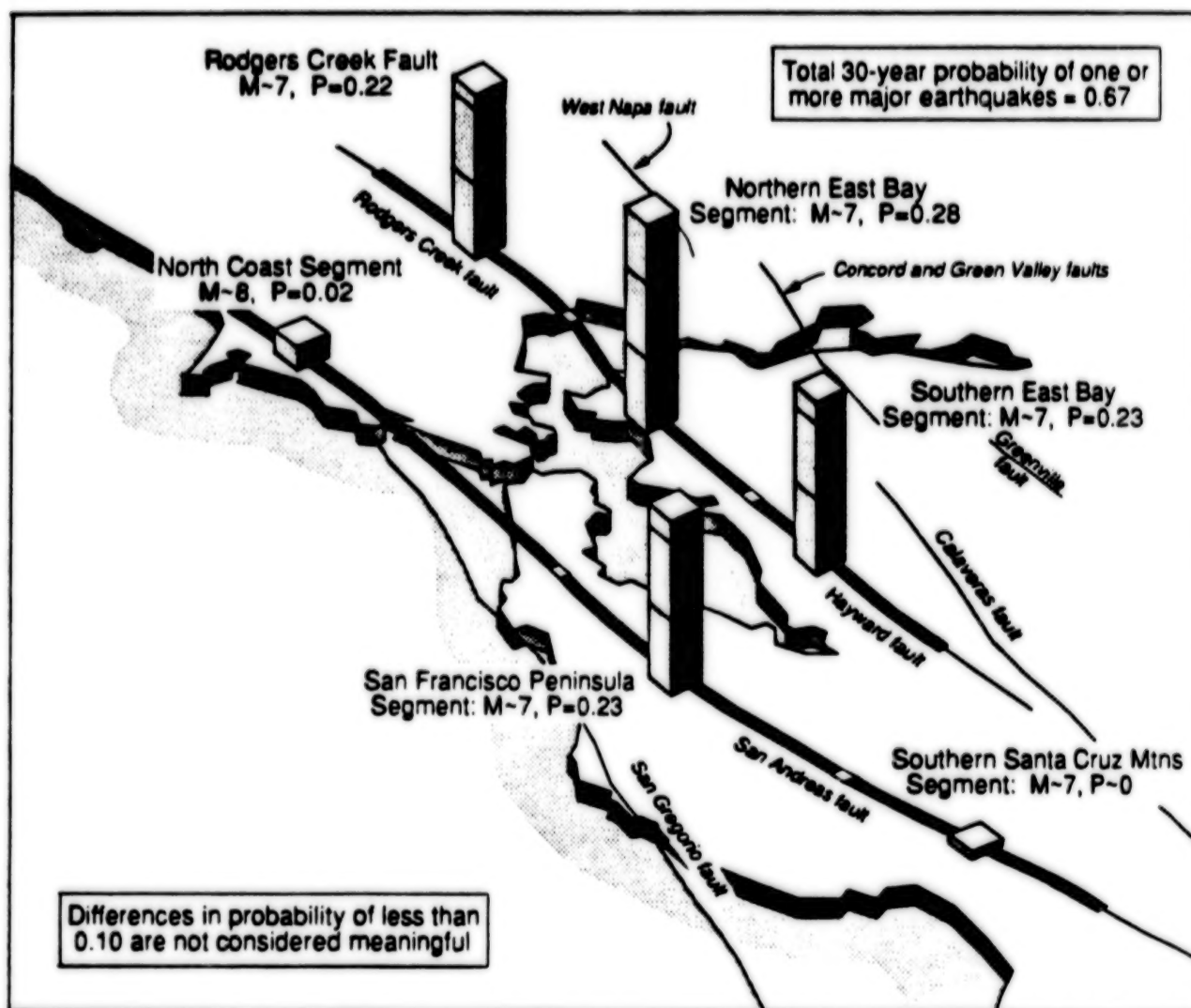


Figure 1. Probabilities for the occurrence of major earthquakes along the San Andreas fault during the 30 year interval 1988-2018 (from Working Group on California Earthquake Probabilities 1988). Note, this forecast is prior to the October 17, 1989 Loma Prieta earthquake, which occurred on the Southern Santa Cruz mountains segment. The post-Lima Prieta probabilities for this segment are now less than 0.01 (see Figure 2).

to occur within the next few years (Bakun and Lindh 1985).

Figure 3 shows the distribution of earthquakes in the United States since 1899. Clearly, earthquakes are not just California's problem. Large damaging earthquakes have occurred in the central and eastern United States during the 19th Century, demonstrating that this region is not immune to strong earthquakes. The 1811-1812 New Madrid, Missouri, series of earthquakes rank as some of the largest events to occur in a stable continental interior. It has been estimated that the recurrence of one of the 1811-1812 events today would cause tens of billions dollars damage (Hamilton and Johnston 1990). Similar damages have been estimated for the recurrence

of other historic events in the central and eastern United States (Harlan and Lindbergh 1988; Scawthorn and Harris 1989). Hence, for most of the U. S. it is not a matter of if but rather when and where future earthquakes will occur. Eastern and central U. S. earthquakes are capable of producing damage over larger areas than their counterparts in California, and the higher occurrence rates in the west are balanced by the lower rate of attenuation of damaging vibrations in the east. Currently, in the area east of the Rocky Mountains, the probability for an earthquake of magnitude greater than 6.0 in the next 30 years is about 0.5. This is approximately 2/3 of the likelihood for an event with a similar damage area in California (Nishenko and Bollinger 1990).

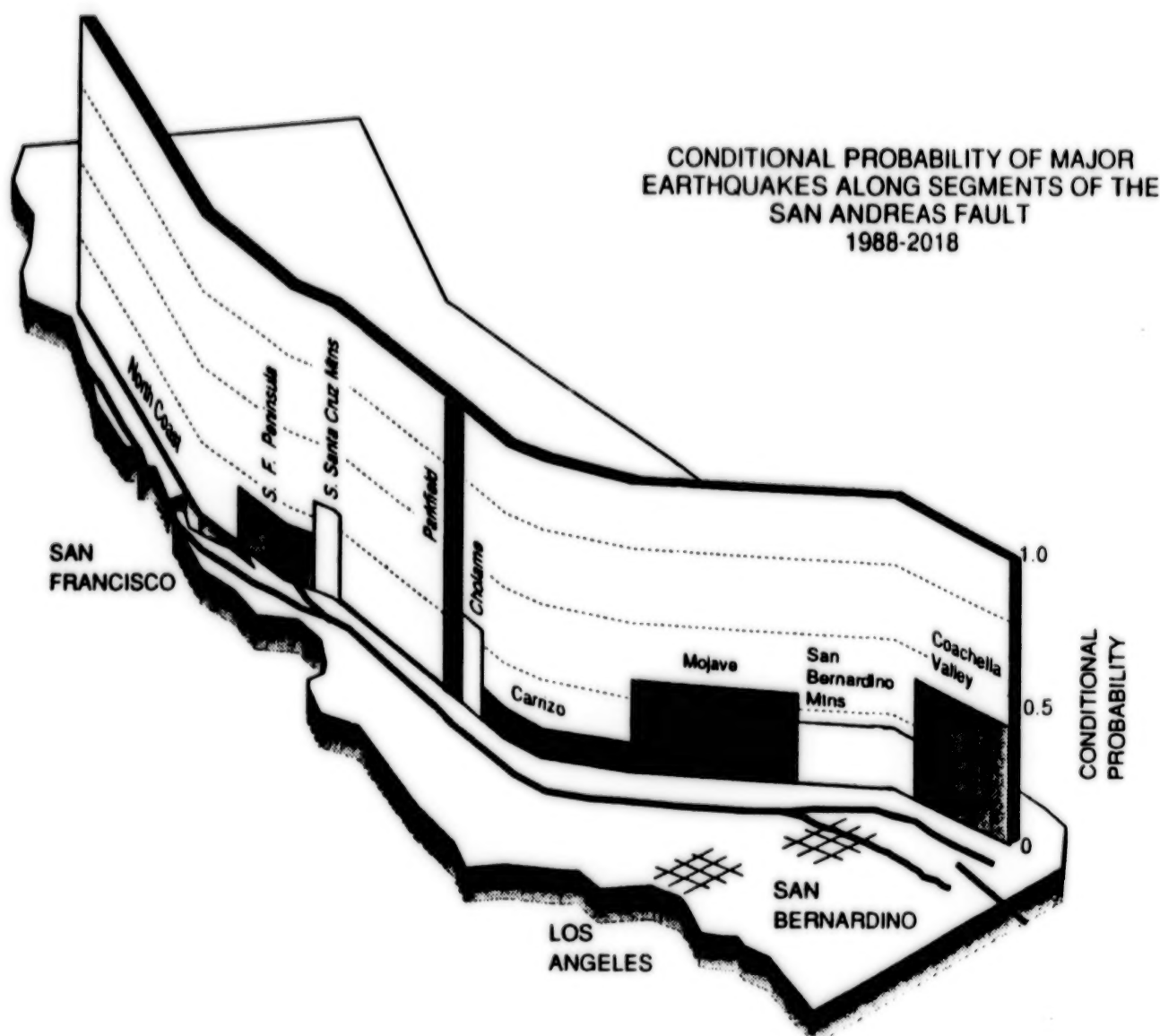


Figure 2. Probabilities for the occurrence of large earthquakes ( $m > 7$ ) in the San Francisco Bay region during the 30 year interval 1990-2020 (from Working Group on California Earthquake Probabilities 1990). The column heights are proportional to the 30 year probability of earthquake rupture on the indicated faults.

### **POST-EARTHQUAKE RESPONSE AND INFORMATION**

The National Earthquake Information Center (NEIC), a part of the U. S. Geological Survey, Department of Interior, is the foremost collector of rapid earthquake information in the world and has the responsibility for the Earthquake Early Alerting Service (EEAS) and for the publication and distribution of earthquake data.

The Earthquake Early Alerting Service is a 24-hour-a-day mission which requires the NEIC to determine the location and magnitude of significant earthquakes in the United States and around the world as

rapidly and accurately as possible and to communicate this information to concerned national and international agencies, scientists, and the general public. The information is provided to federal and state government agencies who are responsible for emergency responses, to government public information channels, to national and international news media, to scientific groups, and to private citizens who request information. In the case of damaging earthquakes in a foreign country, the information is passed to the staffs of American embassies and consulates in the affected countries and to the United Nations Disaster Relief Organization (UNDRO).

The Early Alerting Service is triggered by the recording of ground motion at four seismograph stations

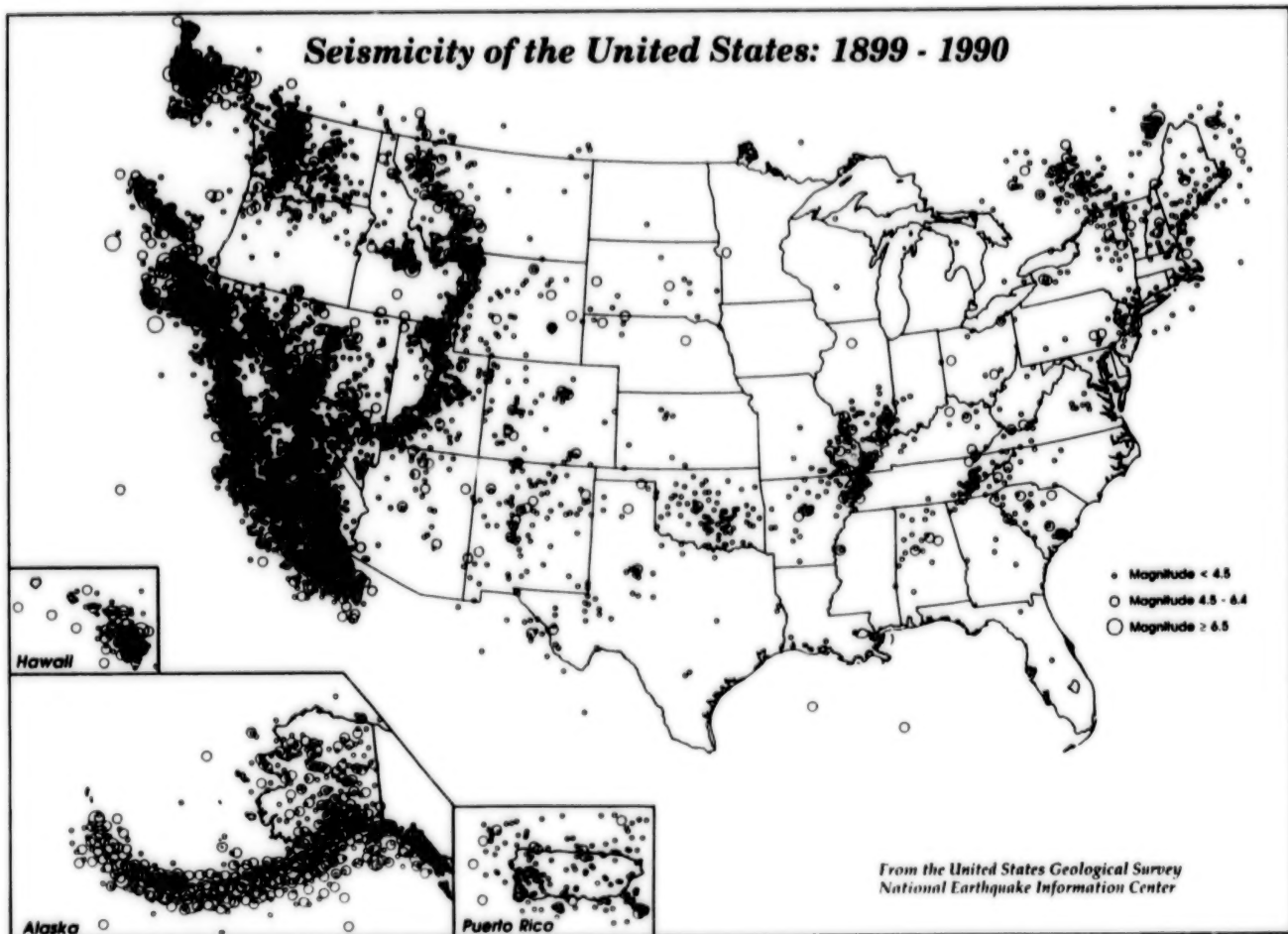


Figure 3. Seismicity of the United States 1899-1990. Symbol size is proportional to the earthquake magnitude (from the National Earthquake Information Center, Golden, CO).

in the western United States. These signals are telemetered to the NEIC headquarters in Golden, Colorado, where an alarm is set off by any earthquake which registers at least 4.5 on the Richter scale in the contiguous United States, 5.5 in Latin America, South America, and Japan; and 6.5 anywhere else in the world. Once a preliminary epicenter, magnitude, and origin time are determined, and if either the magnitude is greater than 6.5 or the event is known or believed to have caused casualties or damage, the NEIC prepares a release on the earthquake and sends it via various telecommunications networks to the media, other government agencies, disaster relief organizations, and foreign governments. If the earthquake is located in the circum-Pacific region and has the potential for producing a tsunami, the Pacific Tsunami Warning Center is notified. Key civil defense agencies are contacted by telephone over the National Warning System, and telephone calls from the news media and other interested persons are answered.

Following the 1985 Mexico City earthquake, geophysicists from the National Earthquake Information

Center were able to determine the location within 17 minutes after it started. Information was relayed to FEMA, the U. S. Embassy in Mexico City, and to the public. Table 1 lists the chronology of events at NEIC headquarters following that event.

In addition to the Early Alerting Service, the NEIC issues daily, weekly, and monthly determinations of global earthquake locations. Table 2 lists the other information products the NEIC currently provides. Further information about the National Earthquake Information Center can be found in Masse and Needham (1989). Within California, both the Menlo Park and Pasadena offices of the U.S. Geological Survey issue weekly earthquake reports.

Following the occurrence of a major earthquake aftershocks are inevitable and there is a possibility of a second, larger mainshock. Buildings, structures, and other critical facilities that were either weakened or partially damaged during the main event are particularly susceptible to further damage or ruin by subsequent shocks. The specter of continued activity also hampers rescue

**Table 1. SEQUENCE OF EVENTS FOR MEXICAN EARTHQUAKE—19 September 1985**

Local time (MDT)	Elapsed time, in hr : min	Event or activity
<b>September 19:</b>		
<b>7:18 a.m.</b>		<b>Earthquake occurs near the coast of Michoacan State in Mexico.</b>
7:21 a.m.	0:03	<i>P</i> -waves arrive at southernmost U.S. network stations.
7:23 a.m.	0:05	Short-period alarms trigger at NEIC.
7:25 a.m.	0:07	Geophysicists arrive at NEIC and begin to interpret seismograms.
7:27 a.m.	0:09	<i>P</i> -wave arrives at Honolulu.
7:28 a.m.	0:10	Surface wave arrives at NEIC.
7:30 a.m.	0:12	<i>P</i> -waves arrive at stations in France and Italy.
7:35 a.m.	0:17	Preliminary locations obtained — lat 17.8° N., long 102.3° W. Telephone callers report that earthquakes were felt at Houston, Texas, and at Mexico City. First inquiry received from news media.
7:43 a.m.	0:25	Surface wave arrives at Honolulu.
7:48 a.m.	0:30	Call made to Pacific Tsunami Warning Center (PTWC). Location and magnitude information exchanged. Magnitude 7.8 determined for event.
7:49 a.m.	0:31	U.S. National Warning Center notified by "HOT LINE" of location and magnitude of earthquake.
7:52 a.m.	0:34	Surface wave arrives at Shemya Island, Aleutian Islands.
7:55 a.m.	0:37	First Denver television crews arrive at NEIC for live and taped broadcasts.
8:00 a.m.	0:42	Earthquake information given to USGS news media services, who pass it on to all wire services.
8:05 a.m.	0:47	PTWC issues tsunami watch for Pacific region.
8:18 a.m.	1:00	Earthquake release issued by NEIC. Messages sent worldwide via World Meteorological Organization/Global Telecommunications System (WMO/GTS) and to United Nations Disaster Relief Organization (UNDRO) and American Embassy in Mexico City. U.S. network data broadcast worldwide over WMO and to European-Mediterranean Seismological Center (CSEM) Strasbourg, France.
8:19 a.m.	1:01	Earthquake information given to U.S. State Department. Data received by telex from CSEM.
8:20 a.m.	1:02	Data received by telex from Istituto Nazionale de Geofisica (ING) Italy.
8:30 a.m. - 12 m. (noon)	1:12 - 4:42	Calls made to and data received from seismograph stations/networks in Guatemala, Costa Rica, Panama, Colombia, and Bolivia. Attempts made to contact Mexican observatories by telephone and telex.
9:18 a.m.	2:00	Location and magnitude of earthquake made available via computer link to Quick Epicenter Determination (QED).
9:30 a.m.	2:12	First of several calls over the next few days from the Mexican Embassy in Washington, D.C. asking for information about the earthquake.
10:20 a.m.	3:02	PWTC cancels tsunami watch.
12 m. (noon)	4:42	Revised location obtained using additional data — lat 18.13° N., long 102.31° W.
4:00 p.m. - 5:30 p.m.	8:42 - 10:12	Television crews return to film live broadcasts for local and national evening news programs for all national networks, including the CBC in Canada.

efforts and the resumption of normal activities. Currently, probabilistic forecasts of aftershock activity after the mainshock are being developed for California and were issued following the 1989 Loma Prieta earthquake (Reasenber and Jones 1989, 1990). These aftershock hazard forecasts would be issued daily immediately following the event, and gradually decrease in frequency as the hazard decreases.

### EARTHQUAKE INTENSITY

Once an earthquake is located within the United States, the NEIC mails computer addressed questionnaires to postmasters, government personnel, and volunteers within an area around the earthquake epicenter. The area varies with the size of the event, and usually has a radius of 20 to 700 km (Stover 1989). Field surveys are also conducted to evaluate damaging earthquakes. Information collected by these questionnaires

and surveys is invaluable in studying the effects of earthquakes on man made-structures, improving building codes, and interpreting intensity data from older pre-instrumental earthquakes.

The collection and interpretation of earthquake intensity data has led to the development of methodologies to estimate the extent and location of probable earthquake damage immediately following the event. A major earthquake in or near a populated area requires the rapid deployment of emergency services. Yet, because of the earthquake effects on life lines and communications networks, the ability to assess and respond to the emergency response is the development of real-time earthquake damage forecasts. Once the location and size of a major earthquake are determined, the extent of the damaged area (usually associated with Modified Mercalli Intensity VII or greater shaking) can be estimated (Evernden and Thomson 1988). Information about the spatial extent of damage can assist local emergency

**Table 2. NEIC PRODUCTS**

Product	Availability
Earthquake Early Alert Service (EEAS) .....	Immediate
Quick Epicenter Determination (QED) .....	Daily
Preliminary Determination of Epicenters (PDE) .....	Weekly
PDE monthly listing .....	Monthly
Earthquake Data Reports (EDR) .....	Monthly
Moment tensor and first-motion fault-plane solutions ..	Monthly
Radiated energy computations .....	Monthly
Focal spheres of moment-tensor and first-motion solutions with selected GDSN wave forms .....	Monthly
GDSN station day tapes .....	Monthly
GDSN network day tapes .....	Monthly
Event Tapes and waveform plots .....	Monthly
Event CD-ROMs .....	Quarterly
U.S., Alaska, and world seismicity maps .....	Monthly
Hypocenter data file tape .....	Monthly
Hypocenter data file CD-ROMs .....	Yearly
United States Earthquakes .....	Yearly
Global seismicity maps .....	Yearly
State Seismicity maps.	
U.S. Geological Survey reports.	
Outside publications	
Presentations at meetings of professional societies.	

services offices during the deployment of emergency response teams. This capability currently exists for California and is being developed for the rest of the United States.

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# THE NATIONAL WEATHER SERVICE PUBLIC WARNING PROGRAM

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The primary mission of the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) is to provide weather and flood warnings, public forecasts and advisories for all of the United States, its territories, adjacent waters and ocean areas for the protection of life and property.

The NWS has continuously sought procedures and resources to better accomplish its mission and is currently undergoing modernization and restructuring. Technical advances will increase the accuracy and timeliness of warnings. However, more than this alone will be necessary to better protect the public. An integrated warning program which involves the emergency management community, the media and local officials is also required to ensure effective communication of warnings and appropriate public response. Finally, the public has to become more aware of appropriate actions to protect life and property through promotional and educational activities.

Weather affects the lives of almost each American on a daily basis. As indicated in Table 1, The United States experiences many more severe thunderstorms, tornadoes and flash floods than almost all other countries. The greatest U. S. disaster losses are caused by weather and floods, which account for 85% of disasters declared by the president. Each year the U. S. suffers an average loss of several hundred lives and about 5 billion dollars in damage from storms and floods. But major weather or flood events can cause substantial increases in losses. This is illustrated in Table 2. The 1972 flood losses were due mostly to just the Rapid City flood and the flooding from Tropical Storm Agnes.

Effective integrated warning and hazard awareness programs can reduce losses. The worst U. S. natural disaster was the 1900 Galveston hurricane, before such programs were in place. Figure 1 indicates the reduction in fatalities from tornadoes and lightning from the 1940s to 1980s (in spite of increasing population) as these programs have become more effective.

With increasing urbanized land development and coastal populations, there is a greater threat of losses from flooding and hurricanes. Thus, the need for improved integrated warning and hazard awareness programs is imperative. Figure 2 indicates the increased

**Table 1. COMPARISON OF WEATHER RISKS**

Country	Severe Thunderstorms	Tornadoes	Severe Winter Storms	Hurricanes, Tropical Cyclones & Typhoons	Flash Floods
USA	10,000 Per/Yr	1000 Per/Yr	10 Per/Yr	10 Per/Yr	1000 Per/ Yr
Australia	500	<100	0	10	100
Canada	500	10	20	0	10
France	100	<10	10	0	10
Fed. Republic of Germany	100	<10	10	0	10
Japan	500	<10	10	10	50
United Kingdom	100	10	10	0	10
USSR	5,000	10	20	0	100
China	10,000	<10	5	20	500

**Table 2. U.S. LOSSES FROM WEATHER AND FLOODS**

	Deaths	Damage (\$Billion)
Average annual hurricane losses	15	0.689
Hurricane Hugo (Sept. 1989)	26	9.5
Average annual flood losses	153	3.47
1972 flood losses (year or Tropical Storm Agnes and Rapid City Flood)	554	4.5
Average annual tornado losses	76	0.78
"Super" Tornado Outbreak (April 3-4, 1974)	315	0.6

population of Florida's coastal counties alone. By the year 2000, 75% of the U. S. population will live within 50 miles of a coastline.

## NWS MODERNIZATION

The NWS plans to improve its warning abilities with a modernization and associated restructuring program. Important advances in the science of hydrometeorology, coupled with major new technological capabili-

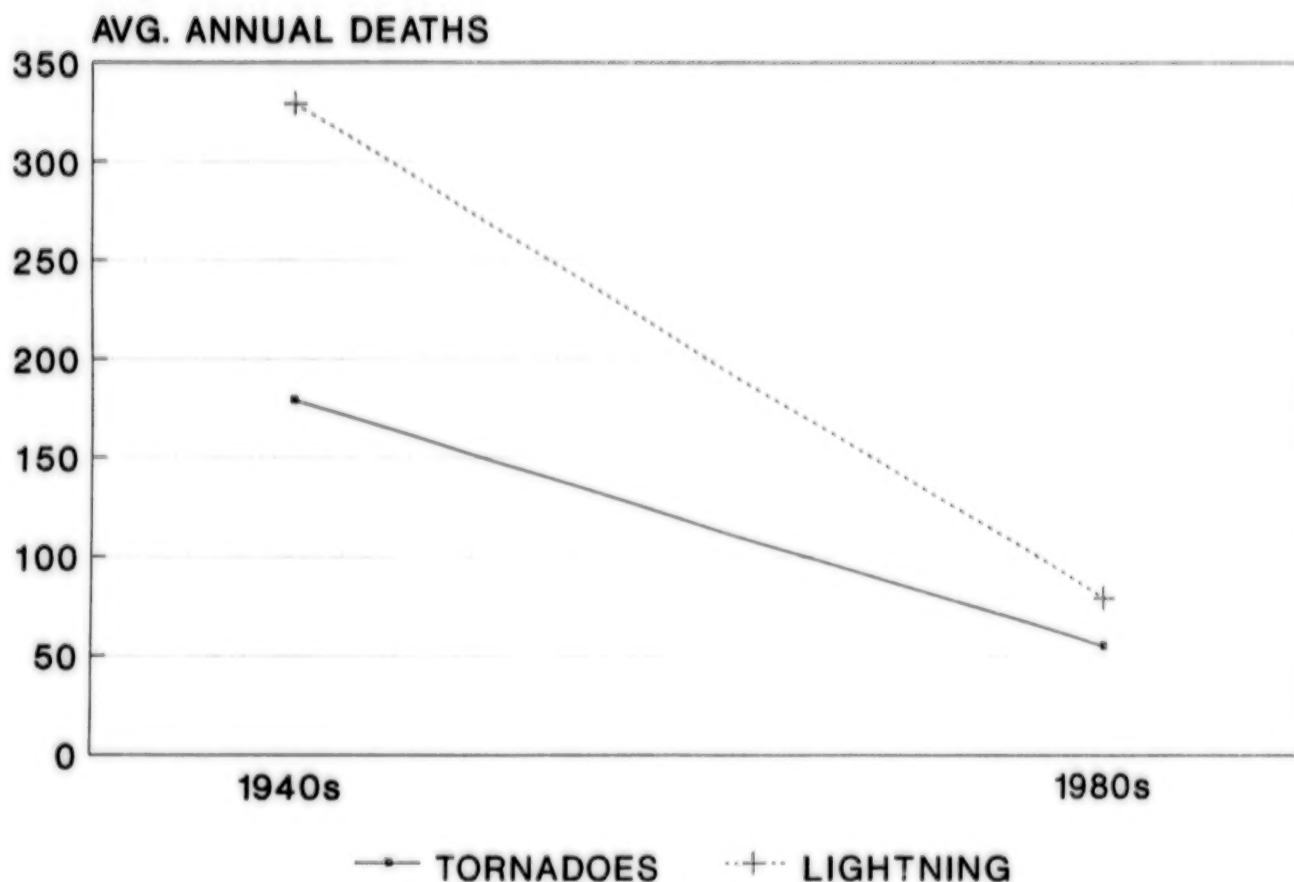


Figure 1. Reduction in Fatalities due to tornadoes and lightning from the 1940s to the 1980s.

ties for observing and analyzing the atmosphere, will provide unprecedented improvements in the next decade. The NWS of the mid 1990s will operate one of the most advanced hydrometeorological warning and forecast systems in the world.

An effective warning and forecast program starts by analyzing the weather on large space and time scales and then focusing on successively smaller scales. This process is informally known as the forecast funnel. This starts with the analysis of hemispheric scale weather features with a lifetime of several days, followed by smaller synoptic scale features (about 300 to 3000 miles in size and 12 to 24 hours in duration), and then finally the mesoscale features (less than 100 miles in size) such as thunderstorms, that may last only around a few hours or less. The MAR consists of several program components that will improve warning and forecasting.

#### Observing Systems

A cornerstone of the modernization effort is the introduction of new, highly automated observing systems. These systems include the Automated Surface Observing System (ASOS), Next Generation Weather Ra-

dar (NEXRAD), advanced geostationary orbiting satellites (advanced GOES), Profilers of winds aloft, and advanced lightning detection systems.

**ASOS:** Surface observations provide the forecaster with precise information concerning the weather near the ground. Today, the surface observation program is still largely manual and labor intensive. Automation will greatly increase the number of observation stations and frequency of observations. The NWS and the Federal Aviation Administration (FAA) are planning a surface observation network consisting of 1000 ASOS units (Figure 3). Plans call for completion of the project by the mid 1990s.

Today's surface observational network produces information available for analysis on an hourly basis. However, more frequent data from more stations would help the meteorologist focus on the development of mesoscale features such as thunderstorms. The ASOS network will provide such data at 15 minute intervals, which will enable the forecaster to better anticipate development of severe thunderstorms. Additional rainfall data from ASOS will improve flash flood prediction.

**NEXRAD:** The NEXRAD system, being developed jointly by the NWS, FAA, and the Air Force, will re-

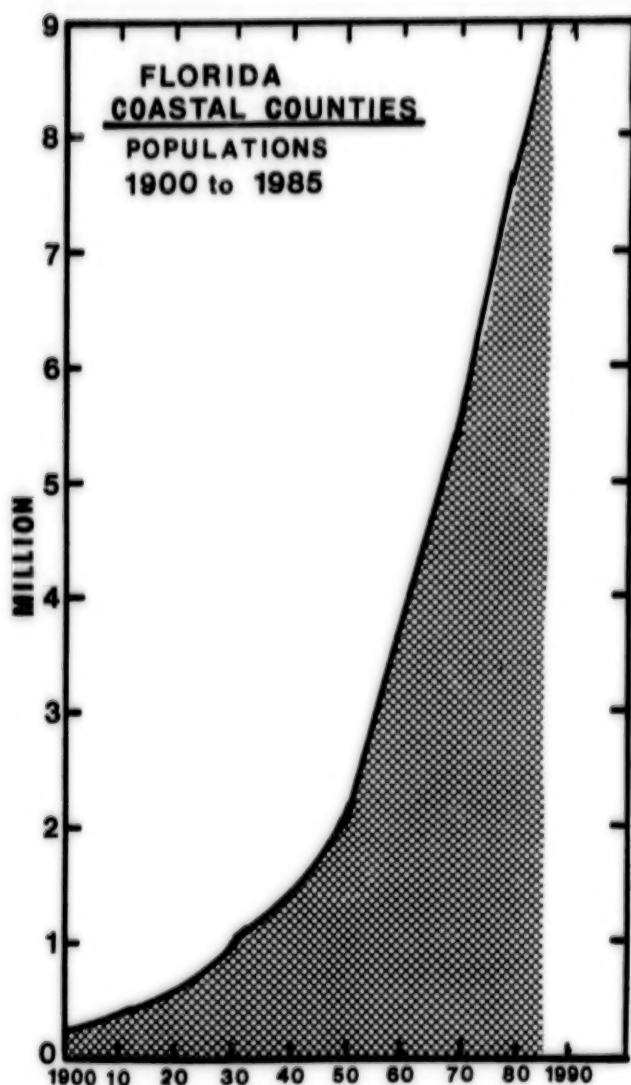


Figure 2. Population increase along Florida coastal counties from 1900 through 1980s.

place the current aging and obsolete radar network developed over 30 years ago. The coverage of NEXRAD will blanket the entire nation east of the Rockies and provide significantly improved coverage in the intermountain west (Figure 4).

Current radars can only estimate location and intensity of precipitation. The more powerful NEXRAD units will not only provide better estimates of precipitation location and intensity, but will also identify characteristic motion patterns in and around thunderstorms and hurricanes. This will provide valuable insight into atmospheric processes before damaging weather occurs and will allow the NWS to be more proactive and increase the lead time and accuracy of tornado, severe thunderstorm and flash flood warnings.

**Advanced GOES:** Advanced geostationary orbiting satellites will better identify, observe and track both

large scale weather systems and small scale local severe storms. This will include winter storms producing freezing precipitation and snow, hurricanes, and tornado producing thunderstorms. Also advanced GOES will provide more accurate satellite-derived rainfall estimates than the current satellite system, and be much more useful in flash flood prediction.

Another valuable aspect of advanced GOES is the ability to produce satellite derived atmospheric soundings of temperature and humidity aloft at much more frequent intervals and locations than the radiosonde balloon releases. This feature will enable the forecaster to better locate areas of potential severe weather and alert the public in advance.

**Profilers of wind aloft:** Radiosonde balloons, launched only twice a day at stations spaced about 300 miles apart, also provide wind velocities aloft. The recent development of radar wind profiling as a means for obtaining continuous measurements of winds aloft over many more locations, provides forecasters with the opportunity for improved prediction of synoptic scale and mesoscale weather systems. This would include enhanced detection of jet streams associated with severe weather. Figure 5 shows an example of winds aloft over Colorado derived from profilers.

A network of 30 profilers over the central U. S. is scheduled to be in place in 1992, with additional profilers expected to be installed across the country during the decade.

**Lightning detection:** The national lightning detection network, which is currently a patchwork of several networks, provides only information on cloud to ground lightning, mainly in summary form over 15 minute intervals. By the end of the decade, the system should be fully integrated, giving continuous information on all types of lightning. This will provide forecasters with better ability to monitor thunderstorm activity.

### Central Computer Guidance

Centralized computers at the National Meteorological Center (NMC) in Washington analyze and provide model weather predictions of the atmosphere on a global scale. The guidance provided from these predictions is essential to local forecasts as meteorologists use the forecast funnel process. In the next few years, NMC will receive new Class VII computers, increasing computational resources by a factor of 100. The new computers, along with the increased data input available from the new observation systems, will allow more sophisticated models to be used that increase the resolution and accuracy of the weather predictions. This will also improve the accuracy of computerized hydrologic forecasts issued by the NWS River Forecast Centers.

## ASOS LOCATIONS NWS and FAA SITES

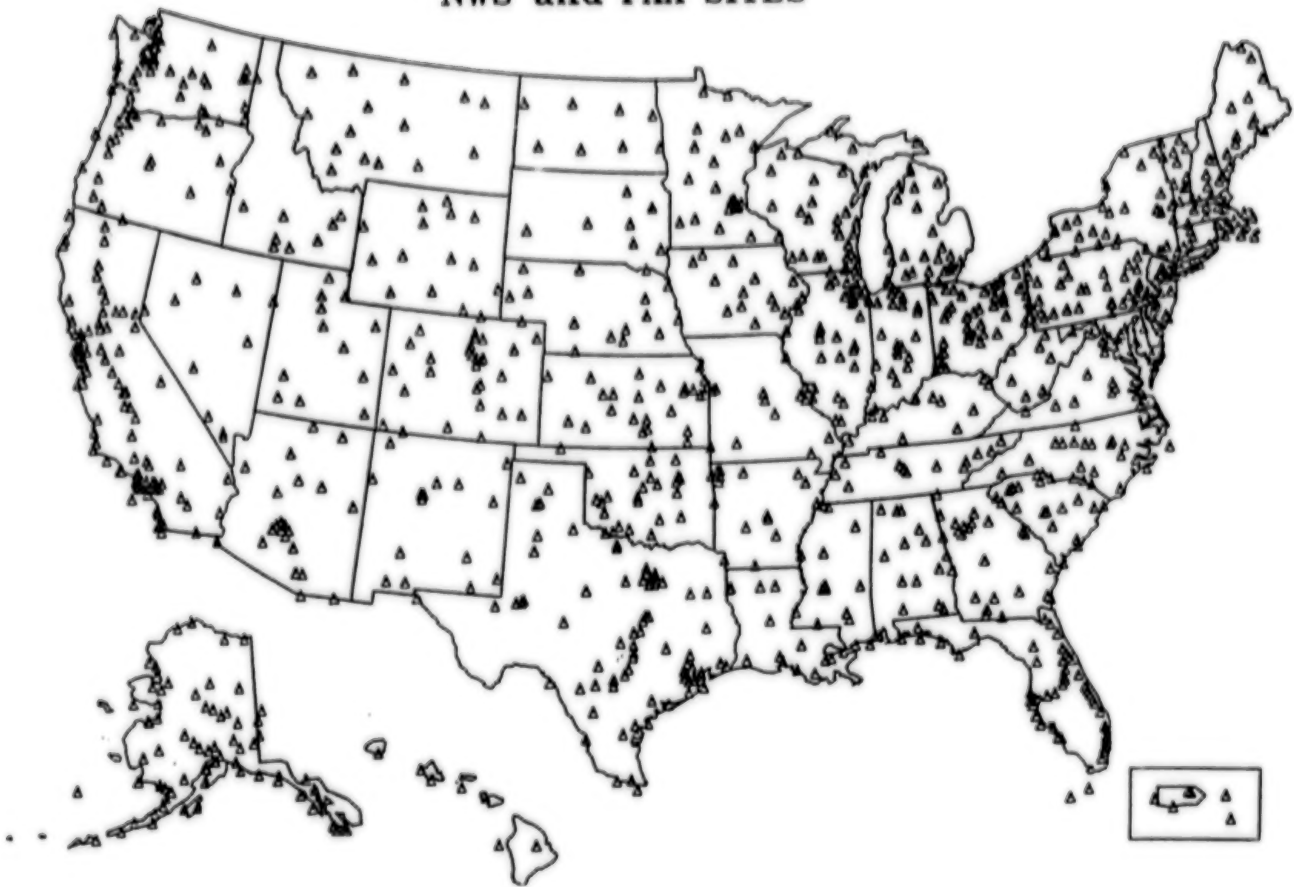


Figure 3. Planned National Weather Service and Federal Aviation Administration surface observation network.

### Advanced Weather Interactive Processing System (AWIPS)

By the end of the decade, with all of the new observation systems providing a continuous flow of billions of bits of meteorological data to each NWS office, The forecaster could quickly be overwhelmed. Therefore, the NWS is designing AWIPS to process this vast array of data and provide the forecaster with more time to concentrate on the warning and forecasting problem.

The AWIPS will be the local processing system in each NWS office which assists the forecaster with warnings and forecasts by doing the following (Friday 1988):

- a. Assimilating the diverse observational data sets and integrating them with each other in various displays.
- b. Supporting warning and forecasting decision making processes with various decision trees.
- c. Facilitating the dissemination of weather products.

Dissemination is discussed in the next section. As can be readily seen in Figure 6, AWIPS is the essential technical element in the modernization for maintaining and improving the integrated warning system.

### Dissemination Systems

Three basic paths of information delivery to various users are critical to the mission of the NWS (Friday 1988). These are:

- a. Information distributed to Emergency Management Officials.
- b. Information distributed directly to the general public and media.
- c. Information to private sector meteorologists

The three main NWS dissemination systems used are the NOAA Weather Wire Service (NWWS), NOAA Weather Radio (NWR) and a collection of data services called the Family of Services (FOS). The NWS warnings and advisories are disseminated immediately on NWWS and NWR. These are the primary sources for



Figure 4. Depiction of the total coverage (at 10,000 ft elevation) provided by the completed National NEXRAD Network. Darkened areas over the Rocky Mountains are gaps in coverage at the 10,000 ft level. NEXRAD coverage will also be provided in Alaska.

most users. The warnings and advisories are then relayed to FOS, which also supplies many other types of weather messages, including satellite imagery and computerized weather forecasts, and is primarily suited for national media vendors such as the wire services. More such data will be made available to users by one-way satellite broadcasts through AWIPS. This will be known as NOAAPORT.

**NWWS:** The NWWS has recently been upgraded to a satellite telecommunications system. The NWWS accepts messages entered through all NWS office data entry modes via an interactive, two-way microearth station. Users have the capability to select only those messages they need to receive by means of a very small aperture one way terminal microearth station.

**NWR:** The NWR radio network of over 380 stations provides continuous 24-hour weather broadcasts within listening range of 90% of the population (Figure 7). The listening area of each station extends to a radius of about 40 miles. The NWR currently uses analog technology with operators manually sending taped or live broad-

casts. A number of manufacturers offer special weather radios that operate on the FM frequencies used by NWR.

During severe weather, the operator can also activate specially designed warning receivers on most weather radios when warnings are issued within the station's listening area. Such receivers either sound an alarm indicating that an emergency exists, alerting the listener to turn the receiver up to audible volume, or when operated in a muted mode, are automatically turned on so that the warning message is heard. Warning alarm receivers are especially valuable for schools, hospitals, emergency managers and the news media. Many radio and television stations, and cable television stations rebroadcast NWR warnings.

The NWR Specific Area Message Encoder (WRSAME) is an exciting new technology that has been successfully tested and is being installed for use at some NWR stations. The WRSAME is a device connected to a standard NWR program console that puts a special code at the beginning and end of selected messages broadcast over NWR. The code specifies the type of message and

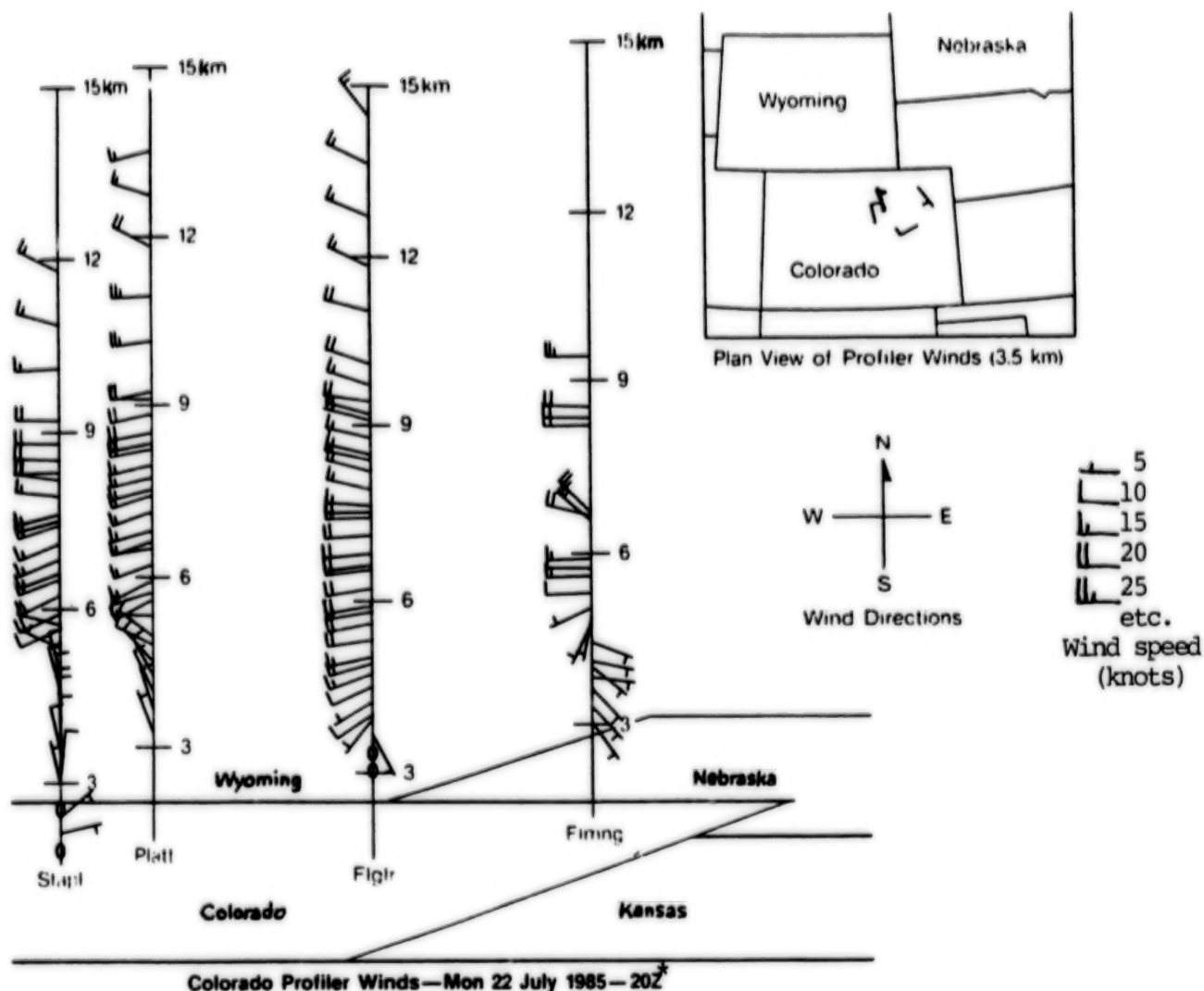


Figure 5. Prospective view and plan view at 3.5 km MSL\* of Colorado mini-network profiler winds. \*Z = universal coordinated time. MSL = height above mean sea level.

area the message applies to. This provides any users with a decoding device within listening range of the NWR signal the ability to choose for particular counties which specific hazardous weather messages will interrupt the normal programming.

New NWR consoles will replace the current analog consoles later in the decade. These new consoles will be able to take alphanumeric messages from AWIPS to provide automated broadcasts of text-to-speech using digital synthesized voice techniques. This technology will free up more time for NWS personnel to maintain a continuous weather watch. WRSAME will be integrated into all new units.

*Two-way Communication with Emergency Managers:* Reliable direct communication between the NWS and emergency managers at the state and local level are vital during severe weather. Meteorological information, including warnings, is given to the emergency man-

agers, and they give weather and damage reports to the NWS. This government helping government concept is critical to the success of the integrated warning program. Such two-way communication is usually done by telephone, including the use of the National Warning System (NAWAS).

However, the NWS has been making arrangements to share information through special high speed data lines with sophisticated emergency managers. The NWS has been sharing data in this way with the New York Statewide Police Information Network. Many more two-way links will become possible as AWIPS units are installed. The Denver NWS office will receive the first AWIPS and there are plans to have a two way data link between the AWIPS and the Denver Urban Drainage and Flood Control District (UDFCD). The UDFCD will send the NWS detailed rainfall and river stage information to assist in issuing flood warnings, and will receive

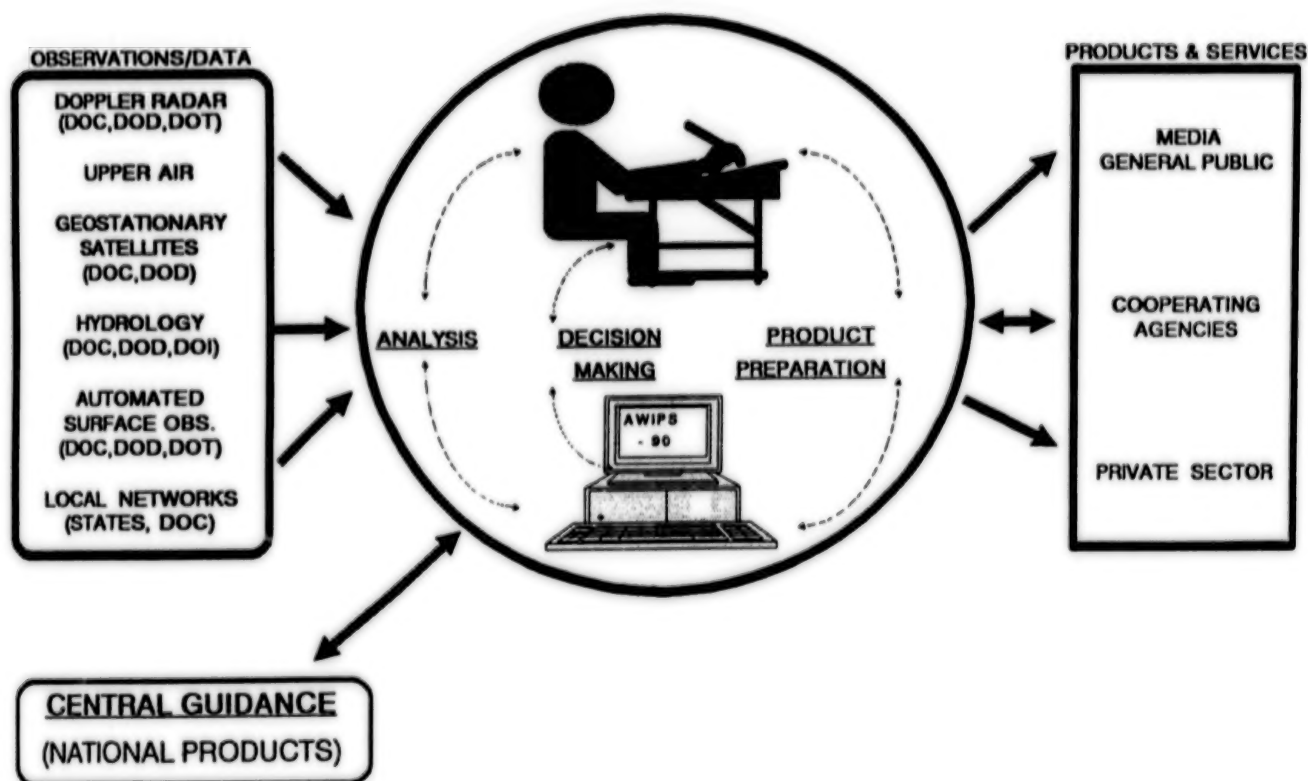


Figure 6. Advanced Weather interactive Processing System (AWIPS) in the future warning and forecast office.



Figure 7. NOAA Weather Radio Network of Stations.

NWS weather data and messages. The UDFCD will use NWS information and its own data and hydrologic computer models to predict localized flooding conditions in advance for affected sub-basins.

#### INTEGRATED WARNING PROGRAM (IWP)

As mentioned in the introduction, technical advances associated with the NWS Modernization alone will not improve effectiveness in warning the public. An IWP

(Leik et al. 1981) is necessary that consists of three basic elements:

- Hazard detection and warning
- Dissemination of the warning and its proper understanding by the public
- Appropriate public response

Warnings alone will not stimulate the appropriate response. Human response to live threatening events is often constrained by cultural assumptions and social values (Drabek 1987). Besides the warning message, people need additional information confirming their personal risk before taking action. Social scientists E. J. Baker and T.M. Carter reported that during a hurricane threat people took protective actions (such as evacuation) based on perceptions of costs and benefits from information received (Vogt and Sorensen 1987). The same is true for other hazardous events (Drabek 1987). People tend to select those actions that will cost the least and require the least amount of action, and their time frame of reference is often limited. When a flood warning is issued, additional information to confirm risk is needed to get a response for someone who says, "I've lived here 20 years and it's never flooded."

The NWS is only part of the total emergency management community, with each member having their own roles and functions to ensure a successful IWP. This community also includes elected officials and Emer-

agency Managers at local, state, and federal levels, and local decision makers such as school and private industry officials.

The NWS is working with the other members of the emergency management community for an effective IWP in the following ways:

- a. Providing emergency managers with more data so they can access their community risks and make timely informed critical decisions.
- b. Learning the requirements and critical thresholds for action by emergency managers.
- c. Receiving local data sources to improve warning ability.

The two way communication links with emergency managers are vital to these goals. Due to the different capacities and sophistication among emergency management organizations, the NWS will have various approaches to information exchanges. Some organizations such as the UDFCD are quite sophisticated and employ their own meteorologists, so the NWS can share considerable technical and scientific data. With others, mainly NWS warnings will be sent in exchange for eyewitness reports.

### HAZARD AWARENESS

One of the most important things that the NWS can do is educate the public to the actions they can take to protect life and property. The NWS distributes many informational brochures and sets up display booths at many public events, often in cooperation with other members of the emergency management community. All NWS offices will be staffed by a Warning and Coordination Meteorologists to manage the hazard awareness program, and thus ensure that the IWP is successful.

Unfortunately, when there is an especially rapid onset of a hazard such as a tornado or flash flood, a warning may not be available to the public in time, despite the best efforts. A devastating tornado hit Raleigh, North Carolina in November of 1988, but only 4 people were killed because of the high level of hazard awareness in the community. An intense education effort began after less powerful tornadoes struck the state in 1984, killing 59. In 1984, surveys showed that many people did not know what to do. However in 1988, most people knew the safe places to go to when the tornado struck, such as a basement, or small interior lower level room away from windows. Since many deaths from flash floods occur in automobiles, lives can be saved if

people avoid driving through viaducts or underpasses having water, near flooding rivers or streams, or through water over roads, whether warnings have been issued or not.

### CONCLUSIONS

The greatest U. S. disaster losses are weather and flood related. Annual losses amount to several hundred lives and 5 billion dollars in losses but major weather and flood events can cause greater losses. In order to mitigate these losses, the NWS is undergoing a modernization and restructuring effort to better detect and warn for hazards. However this is only one part of an integrated warning program (IWP) in which the NWS works with the entire emergency management community. The other two aspects of the IWP are effective communication and understanding of the warnings, and proper community response. More effective information sharing will allow Emergency Managers to better access their risks for critical decision making. The NWS warnings will be more effective with the knowledge of critical thresholds for action. Warnings alone will not stimulate the proper response. People need additional confirmation of their personal risk before taking action.

Hazard awareness will help ensure the success of the IWP. The NWS, together with other agencies, distributes information to the community on the nature of the hazards and protective safe actions to take. The modernized NWS will have a dedicated Warning Coordination Meteorologist in each office to manage an effective hazard awareness program.

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# THE UNITED STATES ARMY CORPS OF ENGINEERS IN MASS DISASTER SITUATIONS

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For over 200 years, the U. S. Army Corps of Engineers has served the nation. The Corps enjoys its reputation as the premier federal agency in the area of disaster response and recovery. Corps involvement in disaster operations can be traced to 1882 when, under General Horatio Wright, the fourteenth Chief of Engineers, it was engaged in flood relief on the lower Mississippi River following major floods. In that operation, the Corps used its fleet of river craft to ferry supplies to disaster victims stranded along the river. In this first use of federal resources to aid natural disaster victims, the Corps emergency operations program was born.

Today's Corps of Engineers is a much different organization, but the tradition of service to the nation in disaster response and recovery endures. The reasons for the Corps' continued involvement and success in this important area stem from the nature of the organization and the people who comprise it. Some fundamental tenets of the Corps' organizational philosophy have persisted through its two centuries of experience. It is those enduring factors that are the foundation of the organization and the reasons for the Corps' continuing success in disaster operations.

Those factors which have served the Corps so well include:

- mission and program orientation
- established relationships with federal, state and local government
- geographical dispersion
- command structure
- organizational flexibility
- engineering and construction contract management capability.

## MISSION

The primary mission of the Corps of Engineers is to support national security. As an agency of the Department of Defense and a Major Command of the Department of the Army, the Corps has mission responsibilities which span the full spectrum of threats to the nation, from natural disaster to war. Although the products and services provided across that spectrum vary, there are commonalities in the processes that bring resources to

bear in response to various threats. Therefore, planning for either natural disaster operations or military mobilization yields synergistic benefits across the spectrum and concomitant resource efficiencies.

## PROGRAMS

The national security objectives of the Corps are achieved through the execution of its two primary program areas: the military construction program and the civil works program. Through these programs the Corps has developed a professional engineering capability with a sophisticated management structure that can be applied quickly in response to national level emergencies. The primary focus of these capabilities in the past has been support of military and industrial mobilization, response to natural and technological disasters and support of large-scale peacetime governmental projects requiring comprehensive engineering design and construction management expertise.

## ESTABLISHED RELATIONSHIPS

The Corps role in mass disasters is derived primarily from the civil works program. The civil works missions of the Corps include flood control, navigation, water supply and water quality, regulatory permits, hydropower, recreation and natural resource management. The civil works mission is the federal government's largest water resource development and management function. This program brings the Corps into daily contact with many agencies of government as well as the general public who are impacted by Corps constructed and operated projects. These projects include ports, harbors and inland waterways, multipurpose reservoirs, local flood control projects and coastal shore protection works. Such projects come into play extensively in water related disasters such as floods or drought. But more importantly, Corps personnel who design, construct and operate these projects are frequently called upon to respond to emergencies in their geographical area of responsibility. Because there are thousands of civil works projects like these across the U. S., the Corps is frequently the first on the scene after a natural disaster.

These same people deal with the public on non-emergency matters and have established credibility and a strong relationship which serves them well under the stress of an emergency.

### **GEOGRAPHICAL DISPERSION**

Geographical dispersion is important from several perspectives. It is likely that there is a Corps presence in the vicinity of most disasters. There are Corps projects along all of the inland waterways at locks and dams as well as at resident engineer offices. The Corps has a regional presence at its eleven division offices and a state presence in its forty district offices, located in major cities across the U. S. In fact, there is a Corps presence in every state except Rhode Island. To a local or state government seeking federal assistance, the Corps is often the first agency to be asked. While there are exceptions, it is likely that there is delegated authority at that location to react to those requests.

In catastrophic natural disasters, loss of conventional communications systems can be a serious impediment to response operations. Corps of Engineers district and division offices have a full range of alternative communications capabilities to back up conventional systems. Very high frequency (VHF) and high frequency single side band (HF SSB) radio communications are present in every office. Most Corps vehicles have mobile VHF capability that can access radio backbone systems that run throughout their area of responsibility. The Corps Headquarters can communicate with every office in the continental U. S. via HF SSB radio relay stations created for its disaster radio net. In Hurricane Hugo, the Corps used satellite communications to communicate from its field operations tent in St. Croix.

### **COMMAND STRUCTURE**

The command structure of the Corps is military and the workforce is civilian. The Corps is commanded by the Chief of Engineers, a lieutenant general and the division offices are commanded by general officers also, normally brigadier generals. The military command structure is carried into the district offices also, where colonels command. Although the command structure of the Corps is military, the organization is comprised primarily of civilians. With a total strength of 48,000 civilians and 900 military officers the organization is predominantly civilian. These civil service employees include a broad spectrum of talent. In addition to the full range of engineering specialties, the Corps employs architects, scientists, archaeologists, wildlife specialists, environmental engineers, park rangers, real estate specialists, lawyers, accountants, water resource planners, computer

analysts and many other specialties. These experts can be called upon quickly in a disaster to provide expertise across a broad range of professions. The Corps has an extensive research and development program which is executed at its several field laboratories across the country.

### **ORGANIZATIONAL FLEXIBILITY**

Soon after the Loma Prieta Earthquake in California, the Corps responded to a request from the Federal Emergency Management Agency (FEMA) to provide 300 engineers to perform structural safety inspections of individual residences and public buildings to assure their safety prior to reoccupation. The request was made after duty hours on a Friday and by Monday morning 350 Corps personnel were on site and ready to go to work in support of the requirement. These engineers came from Corps offices all over the United States, where they left their regular jobs to assist in the emergency operations. It is this flexibility that makes the Corps unique in all the government when it comes to marshaling civilian resources for disaster work.

### **ENGINEERING, DESIGN AND CONTRACT CONSTRUCTION MANAGEMENT**

The Corps of Engineers has a wide range of construction projects to its credit. Not only does it construct large scale civil works facilities such as locks and dams, but its military construction capabilities are unrivaled in the world. It has constructed bases for the Air Force and Army and entire cities for foreign governments. Yet none of this would have been possible without the talents of the engineering and architect firms who assisted in the designs and the construction companies who turned those designs into reality. The Corps of Engineers does not own construction equipment or resources. It manages the contracts for that construction capability. It is through this capability to commit the federal government in a contract agreement that the Corps can harness the considerable resources of the private sector. Whether it is a contract for emergency debris removal, water supplies, critical facility repairs or a host of other essential services in the early hours following a disaster, the Corps calls upon contractors to assist in helping the impacted government restore its critical support systems. The peacetime contractual relationships that have been established over many years serve to expedite the delivery of contract capability without administrative delay.

### **DISASTER EXPERIENCE**

I have covered the factors that allow the Corps to respond quickly in a disaster situation, whether under

Corps authority or at the request of FEMA. A brief overview of the Corps role in the disaster events of 1989 will provide further insight into the scope and depth of the Corps role in disaster response. The experiences of 1989 serve only to illustrate the range of emergencies encountered in a single year. The depth of experiences gained in the past from such events as the Mt. St. Helens Volcano eruption, hurricanes Camille, Agnes and Fredrick and years of involvement with flood emergencies and other water related disasters temper the Corps approach to disaster preparedness, response, recovery and mitigation as well.

### **Drought**

The year began with the Corps already involved in drought operations in the states of North and South Dakota and Iowa. In the midwest, water hauling operations were continued to keep small community water supplies viable throughout the drought. The Corps' Lower Mississippi Valley Division had undertaken extensive dredging on the Mississippi River to maintain navigation as flows continued to drop on the upper Missouri and Mississippi rivers. The Corps was called upon to haul water to many drought distressed communities along the Mississippi River where salt water intrusion had rendered water supplies unusable. The underwater sill that the Corps had constructed in the vicinity of New Orleans had helped contain the salt water intrusion, but navigation continued to be threatened.

### **Alaska Oil Spill**

In March, the Exxon Tanker Valdez struck Bligh Reef in Prince William Sound, Alaska causing one of the most destructive oil spills in U. S. history. The Corps North Pacific Division and Alaska District supported the U. S. Coast Guard and Department of Defense task force sent to assist in the clean up operations. The Corps provided two of its hopper dredges, the Yaquina and the Essayons to assist in sucking up oil from the surface of Prince William Sound. An innovative Corps dredge operator inverted the dredge drag arms and used the drag head to suck oil from the undersurface of the water and into the dredge hopper. The process proved quite successful. The dredges were then used to pump oil from within the containment booms of other booming operations before hauling to shore-side disposal areas. This first use of dredges for oil spill clean-up has prompted formal study of the concept and incorporation of specially modified dredges as an option for clean-up operations in contingency plans.

### **Hurricane Hugo**

On September 17, 1989, Hurricane Hugo struck the U. S. Virgin Islands and Puerto Rico and continued on its track to the U. S. mainland at Charleston, South Carolina. Personnel from the Corps Area Office in San Juan Puerto Rico were on the scene in St. Croix and Puerto Rico the day after the landfall and began preliminary damage assessments. In Puerto Rico, the Corps provided more than 2,000,000 gallons of potable water for hospitals and critical public facilities under its post disaster response authority. This assistance was continued under FEMA direction into the recovery phase. Rapid structural assessments were made of the Carraizo Dam outside of San Juan where overtopping had caused damages to the facility. Other dams and water control structures were also checked to ensure structural and functional viability.

The island of St. Croix was extensively damaged by the category four storm. The island infrastructure was in shambles. There was no power, no water, and transportation was almost impossible due to fallen trees, power poles and debris. Thousands of buildings and private residences were destroyed. The small island's government was unable to cope with such a staggering blow. Even the Virgin Island National Guard facilities were destroyed, except for the Air National guard building, which was used as a recovery center for disaster assistance agencies. The Corps sent engineers from its nearby San Juan Area Office to the island early on, and had to shuttle them to and from the island until there were facilities available to accommodate them on the island.

As preliminary damage assessments and critical requirements were being determined in the Virgin Islands and Puerto Rico, the Corps districts along the Atlantic seaboard were preparing for Hugo's landfall. The Corps' Charleston District was struck on September 21 and like most storm victims, struggled in the early hours after the storm to survive and regroup. After determining that its employees were safe and reestablishing its headquarters building, one day later the Charleston District was ready to provide assistance to state and local government. One of the first missions assigned to the Corps from FEMA was restoring access to hard hit Sullivan Island which had been cut off from the mainland by loss of the Ben Sawyer Bridge, the sole land access to the island. Not only was vehicle access to the island impacted but so was water-borne access along the Atlantic Intercoastal Waterway where one end of the bridge had fallen. The Corps contracted to reset the bridge while the 3rd Engineer Battalion Bridge Company provided ribbon bridge ferry service to the island. Regular Army engineer troops assisted in debris clearance from roadways and powerline rights of way.

In St. Croix, when civil order had been reestablished with the assistance of U. S. federal marshals and troops, recovery operations begin in earnest. FEMA, operating under the authority of the Stafford Act, began to task federal agencies for various public assistance missions. The Corps was tasked with a full range of missions including debris removal (2,000,000 cubic yards), dump site operation, water well development and water distribution, power distribution system assessment and procurement of vehicles for FEMA personnel. The damage to individual residences was staggering. The Corps was tasked to install polyethylene sheeting on the damaged roofs of more than 3000 homes as temporary repairs. An additional 500 houses were repaired on St. Thomas and St John. Permanent repairs are now underway where the Corps Jacksonville District is constructing 100 permanent housing units and rehabilitating over 1300 existing housing units.

### **Beach Dune Restoration**

As the recovery operation progressed in South and North Carolina, a new threat surfaced as a predicted astronomical high tide threatened to reflood portions of the coast in South Carolina. At the state's request, FEMA tasked the Corps to provide emergency beach dune restoration for over 40 miles of coastline. The Corps called in coastal engineering experts from its Coastal Engineering Research Center and rapidly developed plans to construct a protective berm along the threatened beaches. Contracts were let and military assets employed to accomplish the work on schedule. The construction, although somewhat controversial and unconventional, combined with an unusually calm sea for a successful operation.

As with most large scale disasters, recovery work continues for months and sometimes years before restoration is complete, and even then some damage can never be completely restored. So it was with Hurricane Hugo as damage survey reports were performed on public buildings, structures were inspected for structural adequacy and debris was cleared and disposed of. Over 600 Corps personnel from all over the United States assisted the South Atlantic Division in the Hugo clean-up operation. But even as work continued, another challenge waited in the wings. On October 17, an earthquake hit California and the Corps was called once more to action.

### **Fighting on Two Fronts**

Ironically, at the time of the earthquake, the Corps was engaged in another type of contingency. It was playing a Joint Chiefs of Staff directed exercise called Proud Eagle. The exercise was intended to test among

other things, the ability of the Army to mobilize for a national emergency. In the midst of the exercise, the Loma Prieta Earthquake put the Corps to a real test of that capability. Without hesitation, the Headquarters of the Corps formed a second crisis management team to handle the earthquake and continued with the exercise. In the past, military exercises have tested the ability of the Army to respond to both types of contingencies concurrently. The Department of Defense realizes the impact that a major disaster can have on national resources. In this case, however, one of the emergencies was real!

### **Loma Prieta Earthquake**

The commander of the South Pacific Division and his staff were not in the San Francisco Bay area when the earthquake hit. The damage arising from the 7.1 Richter event slowed their return, but it did not prevent the Corps organization from responding. The San Francisco District and the South Pacific Division Office are both located in downtown San Francisco. Both facilities sustained damage. However, the Corps had planned for this eventuality in its earthquake response plan. It had also tested the plan during a Corps conducted exercise in the summer and a FEMA sponsored exercise, Response '89 just a few weeks before the earthquake. The Sacramento District Commander assumed control until the Division Commander's return and the Corps immediately responded. The Commander of the South Pacific Division arrived at Sixth Army Headquarters at the Presidio soon thereafter and orchestrated the recovery operation. Corps structural engineers immediately inspected all Corps dams in the affected area and assisted the state in similar inspections of its facilities. All Corps dams were determined to be safe. However, two local flood control projects in the vicinity of Watsonville sustained considerable foundation damage and have since been reconstructed.

### **Assessing Industrial Viability**

Also being inspected at this time were Department of Defense installations and important industrial facilities, to insure their viability. This unfolded as it should and served as a reminder that the Federal Earthquake Response Plan has evolved from efforts of the now defunct Emergency Mobilization Preparedness Board. Those efforts recognized that a catastrophic natural disaster such as an earthquake could disrupt the readiness of the industrial base and have potential impact on our nation's ability to mobilize. The structure of the current Federal Response Plan which serves as a model for future all-hazards catastrophic response plans was gen-

erally followed in the Loma Prieta earthquake although all provisions of the plan were not implemented. The concept worked well and lessons learned will enable the federal agencies involved to improve upon it.

### **Federal Earthquake Response Plan**

Under the federal response plan, the Corps is charged with coordination of a multiagency emergency support function (ESF) concerned with construction management. It also supports the Department of Defense (DoD) in its ESF for urban search and rescue. Other agencies head other ESF, twelve functional areas in all. The Corps supports many of those ESF either directly or through DoD. In Loma Prieta, the Corps primary missions were damage assessment, building inspection, damage survey report (DSR) preparation for public facilities and inspection of residences for habitability. The Corps took its primary taskings from FEMA Region IX. In all, hundreds of residences were inspected. For Loma Prieta and Hugo operations, over 1000 Corps employees were involved at one point. The operation underscored the need for a broad talent pool of engineers and technicians to inspect the hundreds of different types of structures that were impacted by the earthquake. In a larger event, the drain on the nations' federal and private civil and structural engineering resources would be significant.

### **Nation Assistance**

As the year drew to a close for the Corps, a final challenge began. Operation "Just Cause" unfolded and Manuel Noriega was unseated as Maximum Leader in the successful liberation of Panama. While the Corps was not part of the actual combat operation, it was called upon immediately after the operation to mobilize engineering capability on short notice and apply it in Panama. The Corps' Mobile District, still finishing up its operations in the Virgin Islands from Hugo, shifted its focus to Panama. In cooperation with the U. S. Southern Command, and the Agency for International Development of the U. S. State Department, the Corps was tasked to demolish the Comandancia where Noriega had been headquartered as well as other damaged buildings that served as a reminder to the people of Panama of Noriega's oppressive regime. Temporary facilities were provided for displaced refugees by conversion of an aircraft hanger at Albrook Air Force Base into a mass care center, with necessary water and sanitary facilities.

### **RESOURCE COMMITMENT**

The Corps was very busy in 1989 in disaster operations. Its plans for natural and technological disasters

were tested as well as its plans for nation security emergencies. Its resources and its people were called upon to perform in extreme conditions across the country, on short notice and for uncertain periods of time. The full range of Corps expertise was applied in these emergencies. The support systems that are often taken for granted in non-emergency periods were strained to the limit. Financial and personnel support systems performed well but require refinement in order to be responsive to long duration large scale disasters. At one point, over 1000 Corps personnel were involved in disaster operations for Hurricane Hugo and the Loma Prieta earthquake. The vast majority of these personnel were volunteers who have other job assignments in the organization. The Corps used in excess of 350 man years of effort in disaster work in 1989 and spent in excess of \$65,000,000 in contracts for response and recovery. That equates to the annual workload of a small engineer district.

### **LESSONS LEARNED IN 1989**

What did the Corps learn from these operations? We learned that we have work to do to improve our response time and to become more effective in our methods. Interagency planning and exercises must continue and support systems must be refined to give field office personnel every possible advantage. Communications hardware and computer software support must be compatible among response agencies. Decision support systems must be developed to make sound and timely decisions with the large volume of information (and misinformation) that is generated by response agencies and the media. These decisions have large scale monetary implications but more importantly, potential impacts on life and property. The federal family must revisit its plans, policies and regulations in order to insure a unified federal response, free from indecision and focused in intent. Federal response in the early hours after a disaster must be paramount in our planning endeavors if we are to be remain effective. Personnel must continue to train and realistic exercises must continue to be developed to test our capability against a wide range of threats. Agencies of government must also keep in mind that mass disasters can impact on our national security and plan accordingly. We must also look to increasing involvement in the international arena in disaster response and mitigation as we assume our role in the world community.

### **EPILOGUE**

The Corps of Engineers' capabilities for disaster response and recovery are considerable. That capability has been developed and tested repeatedly by a range of

unforeseen challenges. The future holds further challenges for the Corps as the nation confronts continually changing threats. Natural disasters will continue to recur as man struggles to understand the complexities of his

environment and the geopolitical theater is extremely dynamic, requiring constant vigilance. The Corps stands ready to respond to those challenges as they unfold and to serve the nation with vision and excellence.

## NATIONAL TRANSPORTATION SAFETY BOARD

*Matthew McCormick*

National Transportation Safety Board  
Washington, D. C.

The National Transportation Safety Board (NTSB) investigates transportation related accidents and recommends changes to improve transportation safety. It is up to the agencies within the Federal Government, such as the Federal Aviation Administration (FAA), the National Highway Traffic Safety Administration, Federal Rail Association, and the Coast Guard, to look at our recommendations. We believe they are viable, and hopefully they will act upon those recommendations to improve safety. We have both the media and Congress on our side. Also, we mount publicity, campaigns to bring these issues to the forefront of the traveling public.

This is a description of things that went wrong on a ship which did not, in this instance, result in a disaster. There was a fire on the ship and the passengers were told to go to their lifeboats. However, the generator was not working so one of the crew ran up the back up the stairs, installed the battery, flashed the field, and got the generator on the line. In the meantime the lights were off and there was heavy, black dense smoke spilling into the occupied spaces below deck, where some of the people were sleeping. If you can just imagine the people were not familiar with the vessel and they had practiced only one life boat drill. That drill was on deck, in daylight, and in good weather. The passengers were not familiar with the passageways, the emergency lighting was not adequate at all, the passengers were crawling on their hands and knees and were trying to find members of their family. Finally, they made it to the deck to find mass confusion up above on the lifeboats. Fortunately, the lifeboats were not launched. One gentleman, however, had a heart attack and another was overcome by fumes. A third gentleman slipped in the dark and wrenched his back, was placed in a wheelchair and forgotten for about three hours.

The crew, due to language differences, could not converse with the passengers. The passengers were told to go back to their staterooms to get their life jackets. They were already safe above deck. People below decks could not find some of the life jackets because of the smoke and unfamiliarity with their staterooms. Fortunately, there were no fatalities, no serious injuries, although one gentleman was airlifted from the vessel for observation.

This happened in about 1988, before the same vessel was involved in a fire just recently, where there were

several lives lost. The NTSB had recommended that this vessel have several improvements as a result of the first fire. Unfortunately, there was no one to enforce or make these recommendations mandatory. The NTSB has the congressional mandate to recommend but not regulate, because a regulator should not be the investigator.

The NTSB has been very successful in promoting child safety seats. We also lobbied quite heavily for legislation in all 50 states to raise the drinking law to age 21.

So as you can see, it is not action investigation so much. It is the follow-on through the Congress, through the White House, through the 50 states, to bring about some improvements. We have been very successful in Operation Lifesaver, which is to make the public more aware of grade crossing accidents. Unfortunately, we still investigate quite a few of these type accidents a year. It is not for the want of lights at controlled grade crossings or arms that come down to protect the grade crossings. In most of these cases, the grade crossing is not protected. Where the crossings are protected we are still having fatal accidents. People chose to cross the grade, knowing that a train is in that signal block and taking a chance on hoping to beat it.

The NTSB is comprised of five appointed officials, one of whom is chosen by the President and confirmed by the Senate to be the chairman. Each member serves five years; the chairman serves two; the vice-chairman also serves two. We are probably one of the smallest agencies within the government and have about 300 people. That includes a headquarters staff, located in Washington, D. C., and ten regional offices. Our budget is \$29 million.

The regional offices are comprised of aviation, rail, and highway regional offices. Depending upon where the major rail switching yards might be, or major ports, or major highways, that is where we would put the highway, rail, marine or gas pipeline regional office as well. In Washington, it is comprised primarily of engineers and specialists. This group is the group that you read about in the newspaper who respond to the scene of catastrophic accidents. There is a 10-person go team that is on call 24 hours a day for at least one week. Depending upon workload, some of them may be on for two or three weeks. It is not unusual to have a backlog of five or six or seven major cases on your desk at any one time. The go team itself is made up of experts in areas such as

operations, power plants, weather, survival factors, and human performance. We go to the scene of the accident under the direction of an investigator in charge. This investigator actually runs the show, and it is not unusual to spend 7, 10 or 14 days at the scene gathering factual information.

The following is a description of what the survival factors groups does, because we interface most closely with law enforcement and medical-legal experts. We are at the accident scene to decide two things: why people did or did not survive. In our experience, the aviation accident probably gets the most publicity as far as the worldwide press is concerned. From our investigation techniques, an aviation accident does not differ terribly from an automobile, a school bus, large intercity bus, or train. Impact kinematics may be a bit different, but the injury mechanisms are remarkably similar.

In some of the larger cases, such as the two Delta accidents at Dallas-Fort Worth, the United Airlines accident at Sioux City, or the Continental Airline accident at Denver, three or four people would be at the scene. There would be people documenting the wreckage, interviewing the survivors, and determining the response of the emergency officials, both local and at the airports. An airport that has regular air carrier service, is certificated by the FAA to several levels of index, A through E, depending on the number and size of the airplanes that come in there. We examine the ability of the airport crash-fire rescue departments to respond and once on the scene to adequately do the job, either the rescue people, or to extinguish the fires. In some of these larger accidents they had separate crash-fire-rescue groups at the airport as well as from the community that responded. We also responsible for examining the ability of the community to prepare a plan and then execute this plan in response to an airport emergency, to a gas pipeline, to a hazardous material spill, or to any of the transportation modes.

Following an accident in a local community, after everything has been documented and examined, we will see how their response measured up against their plan. We will sit down with the local police, fire, sheriff, civil defense, and hospitals to see how they performed.

We find this beneficial to provide a critique following an accident, not immediately afterwards, but maybe a month or two later. There is always something to learn from a critique in a positive manner. We know what we did wrong and it will not happen again because we put these things into effect.

A Continental Airline airplane crashed on takeoff in Denver, resulting in numerous problems that hampered the rescue effort. The plane had flipped onto its' back, had one wing torn off, and the other wing was sitting there full of fuel. No one knew how to take the

fuel out of the wing as they had no procedures for dealing with a wing upside down. The cabin had crushed down to probably 1 m. People were still inside the plane for up to five hours after the crash. Six of these people died of mechanical asphyxia during that time. The rescue people physically could not get to them. There was not that much room left for the rescue people to crawl inside the airplane and to remove seats and debris as they worked their way forward to where these survivors were. There was no adequate cribbing material to keep the airplane up. It was snowing at the time of the accident and there was snow on the ground. They brought in heaters to keep the rescue people warm and to keep the survivors warm who were trapped inside. The ground began to melt and the airplane sunk lower into the ground. Some rescue personnel had to leave the airport to bring back material to keep the airplane from sinking further and to hold it off the ground.

There were problems with the radio communications. There were so many fire and rescue personnel using so many lights, heaters, and trucks in the vicinity that hand-held radios could not be used. They were not able to communicate to their own trucks 20 m away because of the background noise. People had to use runners.

The rescue people complained there were too many people there. The fire fighters wanted to help but there was only so much space and so much room for people to work. There was only one jaws-of-life extrication tool on the airport and that broke. They had to get the equipment from off the airport property. Fortunately, they had a good mutual assistance plan and could obtain this equipment from off the airport.

So it is the little things that we look for to provide assistance and to critique, not to criticize. The FAA requires a disaster exercise every two years. The NTSB would prefer to see one every year, but we realize that there are economic constraints as well as community concerns to get the necessary people together at one point on a weekend or at night to train and drill.

One of the worst situations you could imagine yourself in occurred at LaGuardia Airport, New York, early in 1990. A USAir flight rejected takeoff, went off the runway onto the landing light pier and hung there. It broke into two pieces with the tail essentially in the water and with two cracks in the airplane. The only two fatalities were due to mechanical asphyxia. This occurred because the floor was shoved up so high, it had pinned these individuals against the ceiling in their seats.

There was one boat at LaGuardia, a Boston whaler. The boat could not be launched because the pickup truck towing the truck could not make it over a small dike to get to the launching area. In the meantime people went out the emergency slides, not knowing they were in the

water. They went into the water and used the flotation cushions. The FAA regulations does not require most airplanes to carry life preservers. The flotation cushion, in the view of the FAA, is adequate to provide flotation until you are rescued. I do not find flotation cushions to be adequate if you are fully clothed and trying to hold onto to these flotation cushions for more than 20 or 30 minutes, all the while trying to keep your head out of the water. To further complicate things for the passengers in the water, there was jet fuel on the water and people swallowing jet fuel. Helicopters and rescue boats created choppy waters. People could not keep their heads out of the water. A meteorologist calculated a one-knot current in the water from the airplane back under the runway. There were now several people now in the water who could not float and were being held up by others who could float or swim. The current brought them under the pier of the extended runway. The fire trucks and rescue personnel were on top of the runway, shining their lights out towards the airplane. However, it was dark under the runway pier. Boats from the Port Authority, police and fire department, and Coast Guard had sides too high to allow the rescuers to lean over to pull anyone on board. The most effective rescue vehicle they had was the Zodiac, a rubber boat, which was low in the water, maneuverable, and held several people. I believe there were only two Zodiacs available and the rest of the boats were sizable utility boats from the Coast Guard and police patrol. Following the accident, we learned that the Coast Guard, even though they were on the scene and were designated scene commander, did not have communications with the police, fire or the Port Authority.

It took some time for the rescue people to know how many people were on board the airplane. The people who were taken off the airplane in boats or who were in the water in boats were taken to three different places on the airport as well as to hospitals. No one knew where anyone went and the numbers did not match. The Coast Guard finally called off the search at 7:09 the next morning. The accident happened in the late afternoon of the previous day. The rescue people knew the numbers but they did not the names; they did not know where they were taken; they did not know how many people were in the water; how many people were taken from the water to the land; etc. So in preplanning for any kind of disaster, you have got to know who you are looking for, how many you are looking for.

Regarding aircraft accidents, be aware that infants are not carried on manifests. There is no requirement for them to be ticketed. A passenger who is 24 months or younger may be held by an adult during landing and takeoff. That infant's name is not going to be on the passenger list, because it does not have a ticket. The

airline may or may not show INF following a parent's name, meaning parent plus infant.

We recently successfully recommended to the FAA, with the airline industry backing and several associations and unions backing, that children two years old and under be restrained in approved car seats on airplanes. To illustrate the importance, in the Sioux City accident, the United DC-10 airplane right wing struck the ground, losing all its fuel. The airplane then broke into several pieces, the portion of the cabin over the wing went inverted and slid through a cornfield. The corn was about 1.5 m high. There were several children on board that airplane. The plane had lost a sizable piece of its center rear engine. The flight attendants knew the airplane was going to make an emergency landing. They prepared the cabin in accordance with their own procedures. Small infants were placed on the floor in front of their parents. The parent would lean forward prior to landing and assume the brace position, placing their hands on the child who was on the floor in front of them. This was the protection offered to children. Following the accident, we were successfully in talking to three of the four parents. This included the woman who lost an infant. What we do know is when the airplane struck and went inverted, the infants became missiles. One infant was torn from the mother's grasp, even though the infant was on the floor. This woman last saw her infant banging it's head along the ceiling, going towards the rear of the airplane. Other parents had similar stories. One mother, after the child bounced up from the floor, was successful in holding it through the rest of the slide as the airplane came to rest.

We started looking at the statistics back as early as 1978. We recommended that the FAA expedite research into better restraints. The outgrowth of that are the car seats you now see on the market. They were approved not only by the FAA but also the Federal Highway Administration. Hundreds of crash tests demonstrated how to better design these seats. Unfortunately, at this time, if you bring a car seat on board an airplane right now, that airline does not have to let you use that seat. That airline could prohibit you from using a car seat. The airline industry has urged its members to cease and desist with this type of practice. If you bring a car seat on board an airplane, you should have the right to use it.

An irony to this was a woman who almost lost a child at Sioux City crash. She bought a car seat after experiencing the problem with this flight. She got on a United airplane with the car seat, used that car seat with her baby in it, until they were connecting with another airline somewhere else. That airline flight attendant told her that FAA rules prevent you from using a car seat, which is absolutely false. She was adamant and was assertive. She stood her ground until finally the flight

attendant and the captain agreed that the car seat could be used. I think it is rather ironic she almost lost her child several days before and a different airline is now telling her that she can not use the seat; that the child was safer being held.

We have a laboratory for metallurgical and voice recorders examinations. All air carrier airplanes and helicopters have a voice recorder that records the last 30 minutes. It is on a continuous spool so it is erased after 30 minutes. The newer planes have digital flight recorder that pick up a hundred or more parameters. They are protected from heat and high impact to withstand the crash forces. The data from the flight recorders, metallurgical examination, on-scene documentation and the interviews of witnesses and survivors allows us to recommend to the NTSB a probable cause for the accident.

The NTSB member on scene who heads the investigation team will call a press conference each afternoon after learning of the progress we have made during the day. It is not unusual for upwards of 100 or more people to be involved in an investigation. Each investigator may have 10 or 15 people working for him, documenting the wreckage, interviewing the survivors, documenting the community response, etc. We refrain from any speculation of probable cause as this is not the investigator's job. It is the job of the five NTSB members to vote upon a probable cause. We may have a hearing following an accident. It is not unusual to have a three or four day hearing with primarily FAA witnesses brought in to testify to the air traffic control aspects. The public hearing will follow the on-scene investigation by maybe three months. We can make recommendations at any time during the investigation. We do not wait until the NTSB report is adopted six months or more after an accident. We will issue a recommendation immediately from the field, with consultation with headquarters, if there is obvious material failure, obvious engine and avionics problems.

We look for the same type of information from a school bus accident investigation, an intercity bus, or an AMTRAC train. The documentation and mechanics of the investigation are almost identical.

We routinely subpoena medical records of the survivors and obtain pathological information. We use the abbreviated injury scale. It was developed in part by the American Academy of Automotive Medicine. We find this quite helpful in gauging how severe the accident was and to evaluate the potential for debilitating or life-threatening injuries. One of the most difficult jobs we have following an accident is finding out where the people came from, inside the bus, inside the train, or inside the airplane. It is extremely important to learn the location of all passengers on a small airplane, where gross weight and center of gravity of the aircraft may be

an issue. On some of these smaller commercial airplanes such as 10 to 15 passenger commuters, we must know the weight of the people and where they were seated. On a long flight, people will change seats. It frequently takes a great deal of leg work and detective work to track the people down, interview them, and show them a seating chart. Not many people remember exactly where they were seated on an airplane. When we walk into the survivors' hotel, motel, or hospital room, show them a chart and ask them to recall their seat, we find their recollection is not that good.

Interviewing the survivors is the toughest job that NTSB investigators have facing them. It is very easy to go out and document the wreckage. It is relatively easy to review fire response or police response from the community. However, it is very difficult to go into a hospital room and interview the survivors. There was a DC-9 crash outside of Atlanta in 1976. Several people were killed, but again we had many survivors. The survivors were in relatively good shape. The airplane broke into several pieces, and the rear five or six or seven rows of the DC-9 ended up in one piece.

People were in relatively good shape, except they had to walk barefoot through fire and debris. To get ready for emergency landing, in those days, they were told to take their shoes off. They walked barefoot through fire and broken metal. Most of them ended up in a burn unit at Grady Memorial Hospital, Atlanta. I spent 3-1/2 weeks commuting between Washington and Atlanta to interview these people, because their condition and treatment would only permit interviews at certain times during the hospital stay.

Interviewing children is helpful. We have found that children, by and large, have pretty good recollection. Their memory is not tainted as it is with adults. They do not reach conclusions because they do not know where the story ends, or how it should end. We have had relatively good information coming from small children.

We find post-mortem information very useful depending on the type of accident. We are interested in learning if the impact conditions are such that the people should have survived, did they not get out because they were trapped with debilitating injuries? Were they possibly unconscious? Were there toxic levels, such as hydrogen cyanide and carbon monoxide, that prevented them from getting out in time? As an example, when the Delta 727 crashed in Dallas there were 14 fatalities, two of whom were in the middle of the airplane. These two were elderly and they were the last ones in the line to try to crawl up the wreckage and then to slide out a crack onto the ground. They did not make it because they died of asphyxia. Twelve other people, including two flight attendants, were trapped in the rear. The airplane had come to rest at a 30-degree roll angle. The door that they

would have used was jammed. They would have had to pull this door up against gravity, on an inclined deck, and then swing the door out, which is probably physically impossible. The other door was not reachable. It would have been over their heads, because of the roll angle. The door going into the tail cone was jammed. There were only one or two traumatic injuries, such as broken ankles. They died of asphyxia. Surviving passengers outside saw faces looking at them through the window, waving.

We determine the impact kinematics in order to recreate the crash forces. It is an engineering exercise

based upon the physical evidence and the information we get from the recorders. Search and rescue is always extremely fascinating, especially with an aircraft that has been missing and presumed down. Knowing what type of search was mounted, the type of aircraft that we use, the time to locate the people, what condition they were in when they got there is interesting.

In summary, the NTSB investigates many different types of transportation related accidents. Once the accident investigation has been completed, we issue a report. We also make recommendations to improve transportation safety.

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## THE MEDICAL-LEGAL INVESTIGATION OF THE CRASH OF AIR FLORIDA 90 WASHINGTON, D. C. JANUARY 13, 1982

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Planning for mass disaster on the part of those who bear the ultimate responsibility for implementing these investigations and interpreting their conclusions is both critically important and hopelessly irrelevant. Obviously, proper thought needs to be given to the logistics of acquiring requisite facilities, supplies and personnel and to mechanisms for obtaining those additional resources that may be beyond the scope of routine medical-legal investigative practice. By the same token, multiple fatality events are unique and dissimilar to the extent that no amount of planning can predict every eventuality or requirement. Murphy's Law notwithstanding, complications and constraints will arise during the course of any such investigation that, looking back with 20/20 hindsight, should probably have been anticipated.

One of the central axioms of the practice of forensic pathology (and of the pursuit of most matters of law enforcement and medical-legal significance, for that matter) is the notion that the more difficult or "important" a case appears to be at first glance, the more comprehensive and compulsively routine should be the elements of the investigation. Mass casualty disasters would certainly qualify in the latter context. Because of the intense publicity involved and the pivotal issues of accurate victim identification, accident reconstruction integrated with considerations of public safety, and potential liability litigation, there is no room for mistake or misstatement. Consequently, it is essential that the various elements of the investigative team work effectively together. Two heads being better than one in most forensic scientific activities, synergism is the expected result of any such coordinated approach. The corollary here is that egos should be left at home. This is a team effort.

In addition, investigative efforts of these types will, for reasons of practicality, employ precisely the same administrative structure that is utilized in more traditional jurisdictional death investigative activities, forming a framework for the expansion necessary to encompass the requirements of a mass casualty disaster. In Washington, D. C., the investigation of the circumstances of all medical examiner cases is accomplished by the homicide branch of the Metropolitan Police Department, in concert with the professional staff of the medical examiner's office. The homicide branch investigates natural deaths, suicides and accidents, as well as homicides.

Consequently, a close working relationship has been established over the years between the two agencies, with, up to 1982 at least, remarkably little attrition of personnel from either unit. It was only necessary to expand upon on-going policies and practices to implement an effective disaster plan. Nevertheless, exigencies of disasters of various types had been discussed in some detail, and the basic structure of the medical examiner system's response initiative had long since been drafted as District Government policy.

Contrary to popular belief, the most important activity of a forensic pathology unit or medical examiners office is not simply to determine the cause of death. While this is certainly one of the consequences of any adequate death investigative effort, understanding the specifics of the fatal event, in terms of providing responses to questions that are asked in all such cases (questions posed by the family, law enforcement, the courts, attorneys, the media and others) and, thereby, correlating the pathology findings with the circumstances of death should be considered the primary benefit of such a program.

The responsibility of a medical examiners office in the investigation of mass disasters includes identifying the victims, documenting the trauma involved and correlating injuries identified with the circumstances of the fatal event. For obvious reasons, each of these goals is a joint effort that requires not only forensic pathology expertise but external assistance from a wide range of experts from other disciplines. Coordination of the resources necessary to complete these various and diverse responsibilities forms the scaffolding of the response to every mass casualty event. In terms of civilian aircraft accident investigation in the United States, the overall authority lies with the National Transportation Safety Board.

### AIR FLORIDA FLIGHT 90

Shortly after 4:00 p.m. on Wednesday, January 13, 1982, during a blinding snowstorm, Air Florida Flight 90 crashed into the Potomac river. The plane was airborne for only a matter of seconds after taking off from Washington National Airport. The flight destination was Tampa, Florida. Seventy-four of the 79 people on the

Boeing 737 perished, plus four occupants of vehicles on the 14th Street Bridge struck by the aircraft as it plunged into the river. One stewardess and four passengers survived, the result of extraordinary heroics on the part of civilian rescuers and the courage and skill of the flight crew of Eagle One, a U. S. Park Police helicopter.

There were three inches of ice on the river surface at the time of the crash, and the ambient temperature was slightly below freezing, steadily declining to below zero during the next 24 hours.

There are both positive and negative attributes in any major disaster, even in terms of a worst case scenario. Unfortunately, attributes of any sort are often discerned only after the fact. Positive attributes in this case included excellent perimeter control of the crash site, a manageable number of fatalities, orderly and sequential recovery of the victims over the course of ten days, optimal preservation of bodies, and the fact that there was no post crash fire. The accident represented the lowest possible speed, lowest possible altitude crash configuration, and although there was extreme trauma generated and massive destruction of the aircraft resulted, there was minimal passenger victim dismemberment, greatly facilitating identification. In addition, the plane struck the inbound span of the bridge, where vehicular traffic was sparse. The outbound span was in gridlock at the time of the crash, the bumper to bumper traffic caused by early discharge of government employees due to the snowstorm.

Negative attributes included the snowstorm, with resulting traffic congestion which hampered access to the crash site, the fact that the aircraft was submerged in 20-30 feet of water and the frigid temperatures. Visibility at the river bottom was approximately 18 inches. Body recovery required the acquisition of large numbers of highly specialized personnel, including military divers, and heavy equipment and constituted a logistical tour de force of the first magnitude. In addition, there was a simultaneous Metro subway accident with three deaths and multiple injuries.

### THE MEDICAL-LEGAL INVESTIGATION

The first report that a plane crash had occurred was communicated to the medical examiners office by the news media, followed immediately thereafter by an avalanche of telephone calls (averaging approximately one per minute for many days) that continued for the duration of the investigation. Calls were received initially from individuals offering assistance (forensic pathologists from other jurisdictions, for example), family members of the as yet unidentified victims and from the media. After the first barrage of calls, it became clear that responding to media requests for information and

completion of official medical examiners office responsibilities were going to be mutually incompatible. Consequently, all media requests were referred to the office of public information of the Metropolitan Police Department. Press releases were funnelled through the Department, and daily news conferences were scheduled by this mechanism, some of which were attended by medical examiners office staff, time permitting. The dissemination of timely and accurate information in tumultuous situations of this type is extremely important and should be a priority consideration. However, there are mechanisms other than the personal involvement of essential medical staff that are effective in this regard.

Based on review of preliminary information regarding the circumstances of the crash, the configuration of the plane and the tentative numbers of victims involved, a number of initial considerations were put into effect the first evening. Poster board was obtained and gridded for case numbers on the vertical axis and case findings at the top, to form a master logistical and identification flow chart. Sufficient medical examiner case numbers, commencing with a "1" (61 in this case), were reserved for crash victims, to ensure consecutive case numbers and to minimize potential discrepancies between the medical examiners office and the crash site numbering systems. The specific array of information to be included in each narrative autopsy report was determined, including affirmatively stated positive and negative anatomic pathology data, a summary section of pertinent autopsy findings and a listing of the toxicology specimens to be submitted. It was determined that a single generic cause of death would apply to all victims from the aircraft, rather than a cause of death based on individual anatomic findings.

In addition, it was decided to attempt to quantitate trauma identified by body region involved. Grade III injuries were deemed to be immediately fatal. Grade II injuries were considered to be life threatening but not immediately fatal. Grade I trauma was nonlife threatening. This classification was implemented because of questions concerning the effectiveness of emergency medical response and the concern that availability of prompt medical treatment might become an issue for further study, and for the purpose of correlating trauma with the circumstances of the crash and with aircraft damage. In the latter regard for example, examination of the lungs and upper airway relative to the possibility of drowning was an important finding to be documented. The presence or absence of soot in the airway would have been of similar value if fire had been a factor.

Sudden deaths are truly accidents of nature. In this regard, they often constitute important and unique opportunities for research, to develop understanding and to recapture something positive from the ashes of tragedy.

Consequently, it is important to consider what, if anything, might be learned from the unique situational dynamics of the event at hand, prior to commencing the investigative process.

It became apparent during the course of the first evening that additional resources would be required to ensure optimal investigative performance. Scribes with knowledge of medical and/or forensic scientific terminology and procedures would permit the performance of more rapid and accurate postmortem examinations, such that diagrams and records of findings could be dictated at the autopsy table. Members of the homicide unit and medical students and pathology residents who happened to be rotating through the agency at the time were utilized for this purpose. A scribe was assigned to each medical examiner/pathologist. Photography assistants were recruited similarly, obviating the necessity for this purpose. A scribe was assigned to each medical examiner/pathologist. Photography assistants were recruited similarly, obviating the necessity for autopsy participants to remove gloves to take photographs. Finally, and not least significant, police personnel were assigned as "bouncers", and were stationed at the building entrances and at the door of the autopsy room. Only those individuals with a need to be present were admitted. This policy markedly curtailed what was rapidly becoming a circus environment, albeit well intentioned, with representatives of the media wandering the administrative section of the building and the curious, most of the latter from the law enforcement community, in the autopsy facility.

A listing of the various resources required in this investigation beyond those normally utilized by an urban medical examiners office is presented in Table 1. Many are included because they represent major quantitative increases in resources and personnel substantially beyond those ordinarily employed (secretarial assistance and photographic/x-ray film, for example).

It was decided to perform complete medical-legal postmortem examinations and a full range of toxicological analyses on the flight crew. In situ examinations were performed on aircraft passengers and on victims from vehicles on the 14th street bridge. In the latter groups of cases, clothing and identifying documents were reviewed and photographed, the external body surfaces were photographed, described and diagrammed, the internal organs were examined and pathology findings were recorded, and appropriate tissues were retained for toxicological analysis and for other purposes. Description of external and internal trauma by diagnosis, in contradistinction to detailed anatomic characterization, greatly facilitated autopsy report completion. Clothing was described and recorded relative type of garment, fabric, color and size, and a watch (preferably

**Table 1. RESOURCES TO BE ACQUIRED**

<b>Material</b>	
Body storage space	Toxicology specimen storage
Body pouches	X-ray equipment/film/developing
Tags (assorted)	Cameras/film/developing
Plastics bags (assorted)	Autopsy supplies
Evidence recovery stakes	
<b>Personnel</b>	
Investigative	Fingerprint
Pathology	Photography
Radiology	Anthropology
Odontology	Serology
Autopsy diener	Secretarial
<b>Information</b>	
Passenger/occupant manifest (how verified?)	Fingerprints
Photographs of victims	Clothing/jewelry last worn.
Medical history (height, weight, surgical and other scars, anomalies and birthmarks)	Dental records/x-rays

including the label) was retained and photographed. Laundry marks were documented. The contents of the pockets and wallets of each victim were recorded and photographed. Identification photographs were obtained. Polaroid format was employed for identification not only of the victim, but also of clothing, personal effects and jewelry. Trauma was documented by 35 mm format. One passenger was not autopsied because of religious objections on the part of the next of kin. However, identification in this case was readily accomplished. Fingerprints were taken by mobile crime laboratory police personnel at the completion of the postmortem examinations.

The specific postmortem examinations format employed in this crash investigation is shown in Table 2. Commencing with clothing, jewelry and personal effects, the format precedes to include those autopsy findings where an affirmative statement as to the presence or absence of a particular anatomic finding was required. The listing is constructed in the general sequence of autopsy performance, terminating with a summary of anatomic findings and a section summarizing in those toxicology samples submitted for analysis. Toxicology samples of blood, vitreous fluid and urine, if available, were obtained on every case. The tissues listed in parentheses were retained where indicated and were submitted for testing for crew members. The final requirement for the pathologist responsible for each case handled was completion of the master autopsy flowsheet. Autopsy flowsheet headings are listed in Table 3.

Investigative personnel, including members of the homicide branch and other experienced death investiga-

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**Table 2. POSTMORTEM EXAMINATION  
FORMAT**

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Personal Effects
Jewelry, wallet, ticket/seal allocation, passport clothing
Clothing
Garment type, color, size, label, laundry marks
Autopsy
Identifying Characteristics
age, race, sex, height/weight, eye/hair color, beard/ mustache, tattoos, surgical and other scars, circumcised, anomalies/birthmarks
Description by diagnosis of external trauma by body region
Description by diagnosis of internal trauma
distribution of fractures, blunt force injury, internal hemorrhage, airway (trauma, soot, drowning, etc.)
Identify appendix, gallbladder, uterus, prior surgery
Listing of anatomic findings
Toxicology
blood, vitreous fluid, urine (stomach contents, lung, liver, kidney, brain)
Preparation of narrative case report
Flow chart completion.

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**Table 3. POSTMORTEM FLOW CHART  
HEADINGS**

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Form of identification
Case number
Name of victim
Medical examiner/pathologist
Age/race/sex
Date of birth
Height/weight
Hair/eye color
Teeth/prostheses
Surgical scars/circumcised
Other scars
Beard/mustache
Tattoos
Other identifiers
Jewelry
Clothing
Remarks/miscellaneous

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tors were split into three primary components, one dispatched to the crash site, one to the medical examiners office and the third to the site where families were housed and where information regarding identification could be acquired and disseminated. These three police investigative units worked closely with medical examiners office, staff, interchanging identification and circumstantial case information as it developed. Bodies recovered from the crash site were tagged and numbered at the site and transported to the medical examiners office. Clothing, jewelry and other identifying parameters were documented and collated at the medical examiners office and the findings communicated to homicide branch members at the next of kin location. Only

after sufficient identifiers were obtained, were family members escorted to the medical examiners office for positive visual identification, which was accomplished either by means of the agency's closed circuit television system or by a polaroid photograph.

The natural urge to remove and examine personal property from the victim at the crash site should be resisted at all costs. Documentation of personal effects should be done only once and is best accomplished at the medical examiners office, so as to lessen the possibility of loss of property and misidentification. Careful monitoring of this policy should be an on-going investigative priority.

In terms of personal effects, a number of the passengers carried large amounts of cash on their persons. One woman had sequestered \$1600 in one of her socks, for example. There were substantial quantities of expensive jewelry among the passenger victims. Accounting for items of this type was implemented by the postmortem examination teams, with the assistance of members of the property unit of the Metropolitan Police Department. In addition, a number of the passengers were purported to be members of the Rapid Deployment Force, travelling to MacDill Air Force Base from meetings in Washington, some with classified materials that required recovery and proper safeguarding.

During the early portion of the investigation, a passenger listing was obtained from the airline. Unfortunately, this listing represented those passengers who had made reservations for the flight, not those who had actually boarded the aircraft. Subsequently, the listing was updated. Additional identifying information (including identification photographs) was obtained from newspapers, employers, personal physicians and dentists of the victims, family members, the military services and from other sources. Submitted photographs were affixed to an autopsy room wall and were an invaluable resource for identification and exclusionary purposes.

The methods employed to make positive identification are listed in Table 4. Visual identification was possible in over 90% of cases, attesting to the lack of fire and dismemberment. The vast majority of individuals were identified by two or more methods.

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**Table 4. METHOD OF IDENTIFICATION**  
(Expressed as percent)

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	%
Visual	91
Personal effects	53
Fingerprints	49
Jewelry	28
Clothing	12
Dental	4

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**Table 5. EXTENT AND DISTRIBUTION OF TRAUMA**

	Head	Neck	Chest	Abdomen	Pelvis
Grade 3	39	10	29	4	1
Grade 2	29	2	29	3	3

Development of an injury-by-anatomic-site classification and a trauma index permitted evaluation of injury patterns relative to survivability, among other considerations. The distribution of injury by body region involved is presented in Table 5. It can be clearly seen that trauma to the upper portions of the body, particularly to the head, accounted for the majority of the injuries inflicted by the decelerative forces incident to the crash. It was estimated that aircraft speed on impact was somewhere in the range of 125-135 MPH. The notion that the plane was intact at the river bottom with passengers still strapped in their seats could not have been further from reality. In fact, down seeing radar images, divers' descriptions and final reconstruction of the aircraft in the hanger at Washington National Airport demonstrated massive destruction, with avulsion and ejection of a large percentage of the passenger seats from the body of the plane. On impact, those seats loaded with passengers tore loose from their floor attachments and travelled at inertial speed toward the front of the aircraft. Many of the injuries identified must certainly have occurred on this basis.

The trauma index constructed is shown in Table 6. Fifty-five victims demonstrated immediately fatal trauma, at one site in 33 instances, at two sites in 17 instances, at three sites in 4 instances and at four sites in one instance. An additional 10 victims demonstrated life threatening injuries at two sites. Six cases exhibited Grade 2 trauma to the head and were probably unconscious on impact. One victim suffered Grade 2 injury to the chest, multiple rib and extremity fractures and blunt force head trauma, the latter likely resulting in unconsciousness. One passenger exhibited no injury, presumably the "Good Samaritan" who passed the helicopter life ring to others

**Table 6. TRAUMA INDEX**

	Number of cases
Grade 3	55
Grade 2 (two sites)	10
Grade 2 (head)	6
Grade 2 (chest)	1
No trauma	1
No autopsy	1

instead of affording himself the assured opportunity for his own survival. Drowning and/or hypothermia are likely mechanisms of death in this case. Examination of all of the air crash victims for evidence of drowning (a diagnosis that is based primarily on the circumstances of death rather than the pathology identified) revealed as many Grade 3 trauma victims with pathology consistent with drowning as Grade 2 victims.

Fifty-eight of 74 crash victims suffered a total of 115 lower extremity fractures, making effective egress from the aircraft problematical at best, even if egress had been theoretically possible. In addition, in 49 cases there were fractures of the upper extremities. Only nine victims were without extremity fractures. The data are represented in Table 7.

**Table 7. EXTREMITY FRACTURES**

	Cases	Total fractures	Fractures/case
Upper	49/74	62	0.8
Lower	58/74	115	1.6
Cases without extremity fractures - 9			

## CONCLUSION

It is no secret that the investigation of a multiple casualty disaster is a difficult and a complicated task under the best of circumstances. Less well appreciated is the emotional toll taken in attempting to bring order from the chaos of massive sudden death. In the Air Florida investigation, the emotional difficulties inherent in the exercise seemed markedly intensified by the fact that the victims were, for the most part, not massively traumatized. They could have been any one of us. It would have been useful had psychiatric or psychological counseling been available for all crash investigation participants.

There were many heroes spawned from this tragedy, from the U. S. Park Police helicopter crew and the civilian rescuers to some 45 professional divers from the Navy, Army and Coast Guard who spent ten days risking their lives at the bottom of the Potomac river. Nobody involved in the investigation came away from the experience unaffected, untouched or unchanged by the humanity of what they had experienced.

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## CRASH OF PACIFIC SOUTHWEST AIRLINES (PSA) FLIGHT 1771

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Libraries and other sources of law enforcement information throughout the world contain thousands of references and volumes of books devoted to the acceptable, technical aspects of conducting crime scene investigations. However, there is a conspicuous absence of information related to the subject of organizing large-scale crime scene investigations such as the crash of Pacific Southwest Airlines (PSA) Flight 1771, on December 7, 1987. The reason for this is rather obvious. Most law enforcement agencies are never exposed to a massive crime scene search that lasts for days (or weeks) or one that involves the jurisdictional interests of numerous public safety organizations. In addition, many law enforcement agencies make an assumption that their standardized crime scene policies and procedures will provide an adequate leadership and organizational framework for all situations.

In 1982, the Federal Bureau of Investigation (FBI) chose not to rely on good fortune to provide an absence of large-scale crime scene situations during the 1984 Summer Olympics held in Los Angeles, California, and chose not to test its day-to-day crime scene organizational structure with a possible large bombing or political assassination while under the scrutiny of the news media from all over the world.

As a result, the Los Angeles Division of the FBI developed an Emergency Response Plan for the 1984 Olympic Games. An Evidence Response Team was included in that plan. Twenty-eight Special Agents were selected, trained, and equipped to respond to major crime scene investigations and searches. Although the 1984 Olympic Games were relatively uneventful for the FBI, the Los Angeles Division did not disband the Evidence Response Team.

Since 1984, this team has proven to be a valuable investigative asset. It has been called upon several times each year to organize and lead large-scale search and seizure operations, to conduct bombing crime scene investigations and, in one instance, to investigate the crash scene of a commercial aircraft.

On December 7, 1987, at 4:14 p. m., an air traffic controller received a radio transmission from Pacific Southwest Airlines Flight 1771, en route from Los Angeles to San Francisco, in which the pilot stated that shots had been fired aboard the aircraft. Subsequently, Flight 1771, cruising at 6,096 m (24,000 ft), lost altitude

and disappeared from the radar scope over San Luis Obispo County, California. The FBI and the San Luis Obispo County Sheriff's Department were notified about the shots being fired prior to the aircraft's disappearance. Witnesses also advised the Sheriff's Department that a commercial airliner had been seen in a vertical dive and an explosion was heard just before it crashed into a hillside located between Morro Bay and Paso Robles, California.

The San Luis Obispo County Sheriff's Department immediately responded to the hillside crash site. They were able to locate the cockpit voice recorder, but found no survivors among the 38 passengers and 5 crew members. Although the British Aerospace 146 Aircraft (200 series, 4-engine jet), configured for 83 passengers, weighed approximately 54,431 kg, a brief inspection of the crash site revealed only a large volume of small debris scattered over a 20 acre area and a crater that was approximately 1.5 m deep, 4.6 m wide and 9.1 m long. The crash site was secured and guarded by the Sheriff's Department until a detailed crime scene investigation could commence in daylight hours.

That same evening, while the Los Angeles FBI Evidence Response Team was en route to the crash site, other Los Angeles FBI agents made routine inquiries into the identities of the passengers and the PSA crew. It was determined that U. S. Air had recently acquired PSA in a corporate take-over. It was also quickly determined that one U. S. Air employee and one former U. S. Air employee were passengers on Flight 1771. U. S. Air Supervisor Ray Thompson, who regularly commuted between his job in Los Angeles and his home in the San Francisco area, was aboard the ill-fated flight in seat 3-C. Also, David Burke, a former U.S. Air customer service representative, who had been fired by Thompson over allegations of petty theft, had purchased a one-way ticket for this flight and was assigned seat 5-F (across the aisle from his former supervisor).

The next morning, before daylight, a meeting was held in order to coordinate the investigative activities of the FBI, the San Luis Obispo County Sheriff's Department, and the United States National Transportation Safety Board (NTSB) personnel. Since there were strong indications that Federal criminal violations had occurred, including "Crime Aboard an Aircraft" and "Destruction of an Aircraft", the FBI Evidence Response Team was

assigned the responsibility for recovering evidence of a crime. The Sheriff's Department and their volunteer Search and Rescue Team was designated to recover all body tissue and personal effects. The NTSB assumed responsibility for recovering aircraft parts and debris; however, their initial investigative activities would be limited to conducting observations that did not interfere with the crime scene.

Because witnesses had reported an explosion had been heard before the plane crashed and because I was both the coordinator of the Los Angeles Evidence Response Team and an experienced bomb crime scene investigator, the Special Agent in Charge of the Los Angeles Division of the FBI placed me in charge of the crime scene. I readily pointed out to the FBI and Sheriff's Department supervisory personnel that neither I nor anyone else present had meaningful experience in conducting crime scene investigations on commercial airline crashes. Nevertheless, I noted that the dispersal of debris appeared to be similar to a large bombing crime scene and expressed optimism that we could organize and carry out a very thorough crime scene investigation.

I told the assembled supervisors that in my experience the success or failure of large, long-term crime scenes was more dependent on the morale of the searches and the spirit of cooperation between the investigative entities than on the physical obstacles present. Specifically, I explained to the Sheriff and FBI Special Agent in Charge that the searchers should be briefed on all significant developments, as they occurred, and that they should be given frequent rest breaks in order to sustain their effectiveness (past experience had made it apparent that 30, 40, and 50 year old Sheriff's deputies and FBI agents were not used to spending 8 to 12 hours a day engaged in strenuous physical activity — especially if it lasted for a number of days). I also requested authority to have all significant physical criminal evidence recovered, initialed, and dated by both an FBI Agent and a deputy. In other words, regardless of who saw it first, both departments would participate in the recovery of evidence of a crime. In addition, I suggested that when the FBI, Sheriff's Department, and NTSB on-site command post were being set up, every effort should be made to ensure there was a timely and free flow of information between the crime scene investigators and the agents and deputies conducting interviews associated with this case.

After conducting a preliminary survey of the crash site in a helicopter and inspecting the entire area on foot, I briefed the crime scene searchers. Stressed was the need to be conscious of personal safety while working around sharp debris and human tissue, the need for maintaining a secure crime scene that was not contaminated by curious citizens, and the need for all present to work

together as a team. There were numerous unanswered questions that had to be resolved. Had there really been an explosion? Since there were no large sections of the plane present, did that mean there was more wreckage which blew off into the surrounding hills? Could the lack of large debris be due to the compacting of most of the plane 12.2 m deep into the crater on the hillside (in which case we would be digging for weeks)? Had the plane crashed because a bullet penetrated the fuselage, causing decompression and ripping a large hole in the aircraft? Had a stray bullet hit an oxygen cylinder and caused a mechanical explosion?

Up to this point, most of the searchers (approximately 15 FBI agents and 65 deputies and Search and Rescue volunteers) had not closely observed the crash wreckage and body parts. After they had walked the 32 m from the command post area, located on a paved country road, to the edge of the crime scene, they were able to see that most of the debris was unusually small. The average size of the aircraft wreckage was smaller than a briefcase and almost none was larger than a car door. There were no intact bodies, nor intact limbs or skulls. Most of the body parts were smaller than a human hand. In fact, in most cases, skin was separated from flesh and flesh was separated from bone.

Only after the FBI agents, deputies, and Search and Rescue workers had been briefed and introduced to the crash site and after the entire crime scene had been assessed for safety and security considerations, was the physical crime scene search initiated. The entire area was marked in a grid pattern with wooden stakes. An existing barrier, in the form of a wire fence, was used to divide the area into two sectors. An FBI team leader, photographer, sketch preparer, and searchers were assigned to each sector. Due to the large volume of body tissue and personal effects scattered over the entire area, both humane considerations and logic dictated that the Sheriff's deputies and Search and Rescue personnel should conduct their line search (searchers lined up side-by-side walking through each grid) ahead of the agents. The agents followed, also in a line search, after most of the non-evidentiary items had been removed.

The FBI searchers were instructed to assist the deputies by pointing out valuables or body tissue that might otherwise be overlooked and requested that the deputies assist the FBI agents by pointing out criminal evidence that they observed. Of course, the objective was to bring all of the searchers together as a team and to encourage them to share in both the investigative accomplishments as well as the less pleasant tasks.

After the organizational guidelines had been established, the crime scene search was initiated. The search continued, despite rain throughout the afternoon, until it became obvious that the ground was getting so soft that

evidence could be forced below the surface by the searchers' footsteps. The search was terminated about an hour before dark, and the scene was secured by the Sheriff's deputies.

The items recovered on the first day of searching included the flight instrument recorder (essentially destroyed on impact), body tissue, personal effects and valuables, and some items of personal identification of U.S. Air Supervisor Ray Thompson. Also, FBI agents conducting the interviews and non-crime scene investigation determined that former U. S. Air employee David Burke had recently borrowed a .44 caliber magnum revolver from a friend in the San Francisco area. All of these developments were discussed at a crime scene critique which was designed to keep all participants fully informed of the progress of the investigation. These critiques were conducted each evening when darkness necessitated a conclusion to the day's physical crime scene investigation.

The rain stopped during the night and the soil in the area of the crime scene was firm enough to resume searching by daylight the next morning. The requested additional personnel had arrived and were immediately briefed and assigned to various crime scene functions on the second day. Besides the additional FBI agents, deputies, and Search and Rescue volunteers, Special Agent examiners from the FBI Explosives and Firearms Identification Units arrived. Also, the FBI Disaster Team arrived and set up facilities in conjunction with the San Luis Obispo Sheriff's/Coroner deputies, at a local funeral home. They began the grim task of identifying the crash victims.

Late in the morning, an FBI agent located the frame and cylinder of a .44 caliber revolver half-buried in the mud. The grips and the barrel were missing, but 6 expended cartridge casings were still in the cylinder and their primers indicated that they had been fired by the gun's hammer. By mid-afternoon, another FBI agent located the 15.4 cm (6-inch) barrel of a .44 caliber magnum revolver. An expeditious comparison of information determined this was the same gun that David Burke had borrowed from a friend.

By the third day of the plane crash investigation it was necessary to bring in chain saws to gain access to the interior portions of a thicket. Screens and shovels were needed to sift the contents of the area in and around the impact crater. The crater consisted of about 1.5 m of soft soil covering solid rock.

Also, by this time the FBI Explosives Unit examiners had thoroughly analyzed the aircraft debris. It was concluded there was no indication of an explosive device. This conclusion was substantiated by the NTSB investigators, who determined that all of the aircraft was at this crash location but the debris consisted of much

smaller pieces of aircraft than they had recalled seeing at past crime scenes. Normally, aircraft are flying at reduced power and speed and are attempting to avoid a crash, prior to making contact with the ground. There were indications that this one crashed in a vertical dive, at full power.

It was during the second search of the grids that one of the deputies (among the nearly 200 searchers at the scene) turned over an air sickness bag, among the thousands of pieces of paper on the field, with writing on one side. The note read, "Hi Ray. I think it's sort of ironical that we end up like this. I asked for some leniency for my family, remember. Well I got none and you'll get none". The note was written with a ballpoint pen and was unsigned. However, the FBI Laboratory was furnished with comparison samples and confirmed that this note had been written by David Burke.

During that evening's crime scene critique, all of the assembled law enforcement officers listened in hushed silence as the cockpit voice recordings were played several times. Two shots could be heard, apparently in the passenger area, before the pilot notified the air controllers that a gun had been fired aboard. Then, after three shots had been fired in the cockpit area, the aircraft went into a dive. A sixth shot had been fired a few seconds before the impact.

Approximately one minute and thirty-one seconds elapsed between the firing of the first shot and the time of impact. Approximately 25 seconds elapsed between the time the plane went into a dive and the time of impact. At the time of impact, the aircraft was traveling at over 304.8 m per second. The cockpit recording indicated that it broke the sound barrier shortly before it crashed. Therefore, the loud boom heard by witnesses was really a sonic boom.

On the fourth consecutive day of the crime scene investigation, the FBI Evidence Response Team began to devote all of their efforts to assisting with the recovery of body parts and personal effects. They had already searched each grid three times and located very little of evidentiary value on their last search of the area.

During the final hours of the search, one of the San Luis Obispo Sheriff's deputies located the copper jacket from a large caliber bullet. This copper jacket was subsequently matched to the barrel of the .44 magnum revolver that had been recovered earlier. Therefore, out of the thousands of pieces of debris covering this large crime scene, one of the bullets that had been fired aboard the aircraft was recovered by the investigators on the ground.

On the fourth day, the crime scene was released and the field turned over to the NTSB for removal of aircraft debris.

The FBI Disaster Team continued to work diligently with the Sheriff's/Coroner deputies to identify

the passengers and crew. Within a few weeks of the crash, these investigators had sorted through 716.7 kg of human matter to locate enough portions of dental and fingerprint tissue to positively identify 33 of the 43 victims of the crash. One of those identified by fingerprint comparisons was David Burke.

After four days of conducting an intensive crime scene investigation the frame, cylinder, and barrel of the .44 caliber magnum revolver that David Burke had borrowed was recovered as was 6 expended .44 caliber cartridge casings and a .44 caliber copper jacket that had been fired by this gun; also recovered was a revenge note that had been written by David Burke; human tissue

containing David Burke's fingerprints was located as were items of personal identification belonging to both Burke and his former supervisor, Ray Thompson. Certainly, if David Burke had survived, there would have been enough evidence to file criminal charges against him.

Of course, as any experienced crime scene investigator knows, it was very fortunate to have found so much incriminating evidence among such a large volume of debris that was scattered over such a large area. Although, perhaps more importantly, the scales of success were tipped favorably by working hard and being well equipped, well motivated and well organized.

# THE AMTRAK DISASTER: LESSONS AND LEARNING

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This paper is in 2 parts. Part I details the handling of the crash, its aftermath and what we learned from the experience. Part II is a reconstruction of the crash and its antecedents. It is our belief that the reader will find both portions worthwhile. Part II is like a good detective story in which you know who committed the murder, but you must figure out the how and why. Part I is something akin to an architect's blueprint, it is the basis and framework for the structure you are building.

Our hope is that you will find this useful in planning and executing your own hope it never happens great disaster.

## PART I

### PROBLEM: A TRAIN CRASH IN CHASE

Essentially, in terms of sequence of command, the Baltimore County Fire Department — Emergency Medical Services — carried the primary responsibility for the emergency scene. Twelve passenger cars, carrying an unknown number of passengers, lay crushed and bent in a heap on the narrow rail bed. Fire had broken out; cars jugged at unstable angles in bizarre configurations. The sight of hundreds of dazed, bleeding victims held the ominous potential for massive casualties. The fire department had an effective and well-practiced emergency response plan. Their focus became the rescue of passengers, evaluation of the injured and evacuation of victims. As fire-emergency services went into action, the Baltimore County Police, who had arrived at the scene and begun initial rescue efforts, turned to defining the Police role.

#### Security

The crash occurred on a narrow (3/4 mile wide) peninsula of land. The tracks divide the residential communities of Oliver Beach and Harewood Park, with single access roads on each side of the track. In addition, the site is 1/2 mile from the Bird River, which is crossed only by rail bridge. For the police, security in this confined area, as crowds formed, frightened family members converged to the area, and emergency personnel surged on the scene, became a critical issue. The immediate crash vicinity needed to be secured to ensure that

rescue personnel could work without distraction or external danger.

The safe evacuation of passengers and their property, while preserving the scene from curiosity seekers, well-meaning helpers, media and relatives, was another aspect we had to consider. Concerned community members responded to the scene in what would prove a remarkable outpouring of assistance. However, such aid needed order and control before it could prove effective.

#### Traffic Control

The confined area would lead to one of the most severe problems faced. Within 20 minutes of the crash, the already limited access routes became congested with civilian, volunteer and emergency vehicles. It became impossible to get emergency personnel or equipment into or out of the area with any ease. The press of vehicles necessitated we establish an outer security perimeter to facilitate the passage of authorized equipment and personnel, while still considering the needs of local residents. While priority lay with moving immediate rescue equipment, it was important to bring in heavy equipment, cranes, bulldozers, etc., to move the masses of metal trapping many victims. The traffic problem was so severe that it would be six hours before this heavy equipment could be brought to the scene.

#### The Passengers

As passengers were evacuated from the site, either to the medical triage (to determine their level of injury) or to shelters, we needed to expand our security efforts and assistance to rescue personnel.

After an initial survey of the scene, another major problem was perceived. The Colonial #94 train was unreserved, meaning that no names or actual number count of passengers was available. On the basis of the numbers of cars and their capacity, it could only be estimated that as many as 892 possible victims might be on the train. Our full data gathering capacity would be taxed to compile a workable passenger list, not only to aid rescue personnel in estimating the impact of the tragedy, but also to coordinate passenger identities with anxious family members. The train had originated in

Washington, D. C., about one hour from Baltimore. Many of the victims had friends or relatives nearby who flooded phone lines with calls or attempted to visit the scene. Passengers had been dispersed to three temporary shelters, 11 hospitals, several hotels (the uninjured) and a number of neighborhood homes. Our task was one of coordination and accuracy.

Regarding the 16 deceased victims, again the difficult tasks of identification, evidence gathering, and scene preservation fell into police jurisdiction. The number of potential fatalities also added stress to the situation.

### **Multiple Agency Involvement**

One of the complexities in a disaster of this type is the involvement of many agencies, operating on different levels, with varied goals. The fire department, emergency services, and various volunteer rescue groups coordinated with a focus on rescue/evacuation.

As the local support agency, the police acted as liaison with the many other agencies either facilitating the immediate rescue or, in the case of the National Transportation Safety Board (NTSB), investigating the crash under Federal directives. Over 11 agencies, apart from our own operations, were involved. Our goal was to coordinate the efforts and needs of all for the best use of resources and accomplishment of goals.

### **Media Relations**

Media response was immediate and intense. A disaster of such proportions, in the highly populated East Coast area, drew members of not just local print and electronic media, but also from across the country, in search of immediate information. While it was necessary to provide timely information and, in this television era, visual access, it was also necessary to insure that rescue was not hampered, safety was not compromised, and the privacy of victims was not invaded. Such a delicate balance had to be made amidst the difficulties of the site, with limited communications, and an incredible volume of demands for information.

### **Community Needs**

By 7:00 p.m. (6 1/2 hours after impact) the County Executive, Dennis F. Rasmussen, and Chief of Police Neil Behan had reviewed the scene and were mutually concerned about the negative impact on the surrounding community. Significant property damage was incurred in the course of the crash and rescue, some simply because generous citizens opened their homes to victims, rescue personnel and the media. The emotional devastation was just as real and is more lingering. We felt a

responsibility to reassure the community that their welfare was a prime consideration.

Finally, as part of our duty as Baltimore County Police, we needed to maintain quality service to the remainder of the Baltimore County throughout the duration of our concentrated efforts in the Chase area.

### **Resolving the Problem**

This is the scenario that would unfold before the police command staff and officers between 1:31 p.m. on January 4th and 10:45 a.m. on January 6th (when the last command post was closed). Officers had responded to the first call within two minutes and within 14 minutes had begun the first phase of the department's basic graduated emergency response plan. While a core of command and uniformed personnel were advancing to the scene, personnel already at the crash site began preliminary crowd and traffic control and set up initial liaison with the fire department command. With the assistance of the Maryland State Police, critical highways were blocked to all but emergency units.

Within 45 minutes, command personnel had arrived at the scene, initiated a second emergency phase to bring in additional commanders, and had made an assessment of likely command areas. Inner and outer security perimeters were set to divide the areas of responsibility. As additional ranking officers arrived, each would take on one of the growing number of problem areas and initiate necessary action.

By 6:00 p.m. when the first full briefing at a temporary command post took place, several separate action fronts were operational.

#### **Inner Perimeter Coordination**

- crowd control
- site security
- temporary morgue, with crime laboratory personnel
- liaison with other agencies
- assistance in victim transport
- public information coordination and press area

#### **Outer Perimeter Coordination**

- staging area; fire liaison
- traffic management/control
- relief personnel and coordination of manpower
- security of victims in shelters
- facilitate ambulance/helicopter evacuation

Even at the early stages of the operation, it had become apparent that the emergency was complex and very broad in scope. The command response was to divide the efforts into manageable areas of accountability and coordinate in a teamwork approach. Thus, a

defined challenge replaced the uncertain enormity of the disaster.

As soon as communication lines were in place at a permanent command post, the crash scene was divided into three areas for control purposes. Seven operational commands were directed at separate segments of the response.

### **Crash Scene Command**

At the site, security, crowd control, and scene preservation were primary concerns. Security was needed not only at the wreckage, but also at the adjacent press area, temporary morgue and the command post in the nearby residential area. Personnel in this area worked closely with rescue units to facilitate their work.

### **Command Post**

This nerve center served to coordinate commands, compile and centralize a core of information, and in turn act as liaison with outside agencies. While each command operated independently, input from the entire emergency response was drawn together at this hub. Thus commanders had access to a good overview of the entire operation and could obtain feedback on the feasibility of some decisions. Briefings were held every two hours to update information, identify future needs, and brainstorm on courses of action.

The Baltimore County Fire Department, NTSB, Amtrak authorities, Federal Railroad Administration, Maryland State Police, Air National Guard, Baltimore County Traffic Engineering, medical examiner's office, and contacts with local, state, and Federal officials inspecting the disaster were all channelled through the command post to gather and disseminate information or resolve problems.

### **Media Relations**

While the security of the press area and much information gathering was handled by the command post, it became immediately clear that public information demands could not be handled by simply releasing periodic press bulletins. At a central press area near the crash scene, we therefore provided regulated access to information and photo opportunities that would meet media needs without jeopardizing the integrity of the accident scene. Our departmental relationship with the press is — historically — one of openness and accessibility. We attempt to be as accurate and complete as possible. Understanding this, the local press respected the need for containment for safety reasons and for the privacy of victims. They realized that information would

be available as soon as its accuracy was confirmed. As the dimensions of the disaster grew, we were able to build on this trust. With this tone setting in place, national media also cooperated, and was given access through frequent briefings and releases; as many interviews as possible were conducted in person or via telephone and television. At one point a transoceanic interview was conducted with a reporter in New Delhi, India. Arrangements were made to share film footage and provide formal press conferences with representatives of other agencies.

### **Staging Area**

Located 1/2 miles from the crash, this command initially focused on traffic control. Working in liaison with Baltimore County Traffic Engineering, Maryland State Highways and Maryland State Police, the traffic congestion was cleared by sealing the area, and then (because of the confined location) working from the crash site out to open roads.

The fire department triage was set in this area and, as the injured were brought in, we provided security and crowd control. Assisting agencies such as Red Cross, Salvation Army, Civil Defense, and police chaplains and psychological services were also coordinated from here. Debriefing and counseling of rescue personnel were important concerns.

The staging area also handled disbursement of supplies and relief exchanges.

We were able to draw upon a contingent of Explorer Scouts, auxiliary police and our 73rd recruit class to supplement — through traffic control, perimeter search, and other tasks — the 462 sworn personnel who put some 7,423 hours into the operation.

### **Emergency Services**

As passengers were evacuated in the early stages of the response, no record of names or numbers had been made. As soon as it became apparent that not even a quantitative control was made, a command was established to gather passenger data — names and numbers — and ultimately coordinate with concerned families and friends on the condition of their loved ones.

Police officers were dispersed to gather lists from the shelters, hospitals, Amtrak sources, Red Cross and local residences. Although a fairly comprehensive list was obtained within 11 hours, it was evident that there was much duplication. We initiated slow manual comparison until an on-site decision was made to set up a passenger database with a personal computer that could be accessed by different information on the same person (injured, non-injured, hospitalized, etc.). This system

provided a final accurate count and breakdown of passengers, a total of 597 . . . nearly 300 fewer than the 892 originally estimated on the basis that the train may have been filled to capacity.

As deceased victims were identified at the morgue, emergency services acted as informational liaison with the command post, medical examiners and notified next of kin.

### **Temporary Morgue**

In order to identify deceased victims as quickly and accurately as possible, detectives (technical and investigative) worked with state and county medical examiners at the scene in tents brought in and erected by the National Guard. Evidence was gathered and preserved. At the same time, families of passengers unaccounted for were contacted and detailed descriptions obtained. Without seating lists or ticket evidence to correspond to purchasers, identification could only be made on the basis of this physical evidence.

### **Community Needs Response**

The enormous task of assessing the physical, psychological, and sociological damage inflicted on the citizens of the surrounding area was turned over to the area COPE (Citizen Oriented Police Enforcement) unit. COPE is attuned to dealing with community fears and analyzing underlying problems. Through problem solving and innovative action, they work to resolve these issues.

While not a fear of crime, the fears and trauma triggered by the wreck were just as real. Through comprehensive interviews, house-to-house surveys, and community meetings, the COPE officers documented damage, tabulated lists of helpers, implemented stabilization efforts and coordinated community activities and facilitated assistance efforts from outside agencies.

Their accomplishment was extensive and far reaching.

- Within 24 hours of the crash, they prepared a general survey report based on 110 interviews.
- Conducted 1276 interviews to cover all communities in the area.
- Scheduled and attended four community meetings, involving 300 citizens.
- Relayed information to allay community safety concerns regarding the train bridge, chemical contamination, etc.
- Prepared a list of 619 community participants. This report was used subsequently for White House and Maryland State commen-

dations of community heroism.

- Assisted the National Organization for Victim Assistance (NOVA) in debriefing and counseling program for the community to handle the trauma.
- Assisted residents in filing damage claims, securing repairs from Baltimore County Department of Public Works, replacing damaged or lost property.
- Produced a report on all nonprofit organizations and businesses who contributed in any way to the effort.
- Set up a long-term project for trauma counseling and continued resolution of community problems.

The COPE unit's rapid and comprehensive response, involving over 2,102 officer hours, was a shining performance in the grim tragedy of the Amtrak disaster.

### **Critique**

There were many things learned because of the Amtrak crash: things learned during, things learned after, things we are still trying to understand. Some of these things were simple, some complex. But two things became crystal clear — it does not begin when it starts and it is not over when it is finished. While Amtrak is something that will never leave us, it is something that could visit any police agency in America. It is a visitor you must be able to deal with no matter how unwelcome.

First, do not assume it is just an accident. Doing so was our greatest error. In these days when an estimated 3 out of every 10 employees shows up to work under the influence of a chemical substance, it is quite conceivable that alcohol or drugs will be a contributing factor. It did not dawn on us early enough that this crash just might become a criminal investigation. Evidence was removed or buried under by the heavy equipment working to restore service on the line. Next time, we will work forward from the assumption that criminal negligence is involved and we will treat our involvement as a criminal investigation from the beginning.

Second, have relationships with other agencies already established, no matter how remote the need may seem. Know who has what parameters, who needs to be brought in or consulted, and who has ultimate jurisdiction over all facets of the rescue/investigation. These must be established ahead of time so that "internecine warring" does not compromise what needs to be done.

Third, make certain that your command staff know how to work with personnel they can not simply command. There were 11 other agencies — public and private — involved in this operation. People skills are paramount. Without them, there is little coordination

and no cooperation. In our case, each agency had a differing mission. Whether rescue, regulatory, investigatory, or prosecutorial, understanding that we all do not have the same ends but we do have the same means will keep things running smoothly and prevent frayed nerves and fractured egos.

Fourth, pre-plan everything. While we held mock disaster training with our fire department for decades, we had no experience with anything of this magnitude. There should be mock disaster drills for train crashes, plane crashes, explosions on military bases, oil spills, boat crashes, nuclear meltdowns with every agency who has any jurisdiction participating. In addition, even minor details should be taken into account. From accurate, advanced mapping to adequate fuel and refueling stations, from insuring that the appropriate numbers of supervisors accompany officers from other agencies to knowing whom to let in or out; even down to realizing that you must have adequate numbers of spot-a-pots (nature first) — the little things count.

Fifth, know how to deal with the press. Had we not had a long standing, good working relationship with members of both the print and electronic media, the deluge would have overwhelmed us. By making the networks subordinate to the affiliates, by having regularly scheduled briefings throughout the day and night, by establishing a separate central press area, our public information officer was able to meet the disparate demands of both media coverage and crash scene security.

Sixth, understand that politicians and elected officials will be on the scene and will be looking for information. Give them what they need, let them see as much as possible, but don't let them interfere in the criminal investigation. Keep them accurately informed, on a regular basis, and you will allow them to do what they need to do.

Last, but certainly not least, use every resource available to you. The task force approach used during this investigation made everyone's life much easier. The 23 Baltimore County and Amtrak Police assigned to this case were able to break down the workload and successfully conduct an investigation which resulted in bringing of charges against Ricky Gates. Our COPE unit and the local chapter of NOVA were invaluable in helping the community, victims, families and friends deal with the disaster. Local residents helped by allowing us to commandeer their homes for days. We tied up their phones, tore up their yards, used their bathrooms — and they were glad to help. In all these interactions, the police played the key role of facilitator. You can and should become enablers.

Preplanning, including the hard look at policies and procedures mandated by the accreditation process (C.A.L.E.A. Standards), is the real starting point to critical incident management. Community needs during and,

more importantly, after the incident is the real ending to such incidents. Passengers are not the only victims — the community in and around critical incident sites are also victims of circumstance needing our attention.

Benjamin Franklin said, "Always be prepared for the worst. That way, when the best comes, you are pleasantly surprised." Prepare for the worst. Hope it never happens, but assume it will. Doing so will help you deal with your own Amtrak Disaster or any other worst case scenario that comes your way.

## **PART II**

### **THE TRACK BETWEEN BALTIMORE AND GUNPOWDER**

The railroad tracks in place between Baltimore's Penn Station and the Gunpowder River at the Baltimore County and Harford County line are owned and controlled by the National Railroad Passenger Corporation which is better known as Amtrak. The section is considered to be within the Philadelphia Division of the Northeast Corridor of Amtrak.

The Consolidated Rail Corporation which is better known as Conrail is permitted by contractual agreement to operate their freight trains on the Amtrak Northeast Corridor. The trains and personnel of Conrail are subject to Amtrak rules and regulations while on Amtrak lines.

Penn Station is located near milepost 96 of the track. The Bayview Yard, a freight yard, is located between mileposts 92 and 89. The Gunpowder River is located at milepost 79. After the Union Tunnel which is just north of Penn Station there are four tracks over the entire seventeen mile span up to the bridge at the Gunpowder River.

The tracks are designated as Track A, Track 1, Track 2 and Track 3. Track 3 is designated as a high speed track and is primarily used for southbound passenger trains. Track 2 is also a high speed track and is primarily used for northbound passenger trains. The maximum allowable speed on Tracks 2 and 3 is 125 mph for passenger trains and 50 mph for freight trains. The maximum allowable speed on Track 1 is 110 mph for passenger trains and 50 mph for freight trains. Light engines, which are engines not pulling freight, have the maximum speed of 60 mph. The maximum allowable speed for Track A is 80 mph for passenger trains and 50 mph for freight trains.

The four tracks narrow to two tracks at an area which is referred to as the "Gunpow" interlocking just prior to the bridge at the Gunpowder River and is located in Baltimore County.

The tracks in this area were inspected two days prior to January 4, 1987. There were no defects noted.

Each track was in compliance with the minimum Federal Railroad Administration's (FRA) track safety standards for its class.

Train movement in the area is controlled by a train dispatcher located in Philadelphia. It is the responsibility of the dispatcher to monitor all train movements in his area and to communicate to the tower operators how trains are to be routed through the interlockings and the order of the movement of trains. The communications between the dispatcher and the tower operators are by train wire telephone lines. The operator then adjusts the switches and signals in compliance with the routing directions of the dispatcher.

The switches and signals prior to "Gunpow" are operated by remote control by the operator at Edgewood tower which is located at milepost 75.3. To control the switches and signals, the operator pushes a button on the control board at the Edgewood tower which is transmitted electronically to "Gunpow". Safety circuits are checked electronically to assure the change would not conflict with movements on the other tracks. If there are no conflicts, the request is fulfilled. The system is designed to prevent the tower operator from routing two conflicting movements. The wayside signal is then displayed and this fact is transmitted back to the tower. A light on the tower operator's control board indicates the signal is displayed and a light over the switch request indicates the switch is locked. The operator's board also indicates the presence of a train in certain locations on the track.

### THE EVENT RECORDER

The "Gunpow" interlocking is equipped with a microprocessor recorder which is referred to as an event recorder. The event recorder is a microcomputer with 64 input connections which are voltage sensitive. The recorder scans the 64 different possible inputs approximately one thousand times every second. If there is a change in any of the 64 inputs then all 64 are recorded with the time noted to the tenth of a second according to an internal clock within the event recorder. The event recorder performs its own internal test every hour. The recorder at the "Gunpow" interlocking is located at milepost 79.5. It was not damaged in the collision and is secured with signal locks.

The recorder at the "Gunpow" interlocking was equipped to record each signal and switch change request, each signal and switch change for every track and the presence of a train on portions of each track.

### THE CONRAIL CONSIST

The three Conrail locomotives involved in the collision were all GE model number B36-7. The numerical

designations were engines 5044, 5052 and 5045. Each is approximately 62 feet long and each has a fully fueled weight of 271,580 pounds. The 5044 engine was the lead unit on January 4, 1987. This particular locomotive was last used as a lead engine in cab signal territory on December 16, 1986. The last noted cab signal test was on December 15, 1986 with no noted defects. The engine was in proper working order except for the matters mentioned later in this Statement of Facts. Its last maintenance was repair to an air compressor on December 8, 1986.

Unlike the Amtrak Colonial, the Conrail engines were not equipped with automatic train control. This is a safety system that mechanically stops a train if the engineers fail to respond to signals and reduce speed. The Colonial was too close to the interlocking when the consist broke the switch and traveled onto Track 2 for the train to have stopped by manual or mechanical operation.

### PRE-DEPARTURE — JANUARY 4, 1987

Early Sunday morning, January 4, 1987, Conrail TV 22, consisting of three diesel engines numbers 5045, 5052, and 5044 with approximately 40 cars arrived at the Bayview Yard on a relay run from Chicago. Later the same morning, Enola Yard in Harrisburg, Pennsylvania called Bayview requesting engines. Consequently these three engines were placed in service for a light engine run (that is, not carrying freight cars) from Bayview to Enola. As incoming TV 22, the engines were positioned with the 5045 leading and the 5044 in the rear. This placement was reversed for the northbound run.

This northbound run covers 110 miles of track in the northeast corridor where freight and passenger trains commonly share track. Round trip to Enola by train and return by taxi is estimated to take approximately 3-4 hours. On this particular run, the engines' traverse track shared with Amtrak passenger trains until reaching Perryville, a freight yard just north of the Susquehanna River, where they switch over to Conrail's freight only tracks heading west to Enola.

At 10:19 a.m. crew dispatcher Lawrence McKittrick contacted Ricky Gates, as engineer and Edward Cromwell as brakeman from their respective extra lists. Standard procedure allowed the men two hours to report for duty. When called for work, neither man knew with whom he was working. Gates' compensation for his duties on January 4th was \$252.18, based upon union negotiated wage schedules.

At 12:15 p.m. on January 4, 1987, a cold and clear day, Gates and Cromwell, reporting for work at Bayview Yard, contacted Yardmaster David Holstein by phone for further description of their work assignment. Hol-

stein described the engines, their location, and their route and further instructed the Gates and Cromwell to prepare for the run by removing the engines from two ladder, a side track within the yard where they had been sitting since 1:00 a.m. that morning. Trainmaster George Mince who is responsible for the supervision of train crews in the yard and on the road, encountered Gates and Cromwell in the yard office before their departure. Mince noted nothing unusual about either man's behavior or physical condition. Mince observed that Cromwell carried a portable yard radio.

The pulse recorder indicates that at 12:42 p.m. Gates released the automatic brake valve and prepared the engines for service. They contacted Dave Holstein requesting permission for a reverse move onto the lawn from two ladder. Bay Tower authorized the move. The pulse recorder verifies this movement occurred from 12:51 p.m. — 1:04 p.m. From his vantage point, Holstein noted the engines reverse and stop before reaching the lawn track. Whereupon Gates and Cromwell left the engines to enter the yard office once again to obtain fusees (road flares) and paper towels. The crew returned to the engines and continued onto the lawn for pre-departure testing.

### **BRAKE TESTING**

Performance of preliminary air brake tests are recorded on the pulse recorder of each engine when there is an application of brake cylinder pressure and a release of brake valves. Al Ray, Conrail Superintendent of Locomotive Power East, in reviewing the pulse recorder retrieved from the 5044 engine concluded that Ricky Gates failed to conduct the proper air brake pre-departure test. Notwithstanding the failure to test, the National Transportation Safety Board (NTSB) found the brakes functioning as designed when subsequently tested.

### **EQUIPMENT**

When Ricky Gates entered the 5044 engine, he found that the engine lacked a working engine radio. Since there was no maintenance crew working on January 4, Gates removed the radio belonging to the rear engine and attempted to connect it to the lead engine. In his NTSB testimony on January 7, 1987, the Defendant indicated that the wire connectors were bad and the radio was not functioning. He further stated that he obtained permission to use the yard portable. Both Yardmaster David Holstein and Trainmaster George Mince deny giving Gates clearance to use the yard radio. Although Trainmaster Mince was aware of the problem, he concluded from conversation with Gates that he would correct the problem by connecting a radio from the middle

unit before departure. By their admissions, Gates and Cromwell never corrected the situation and relied on the yard radio for communication. It should be noted that although Gates concluded that bad wire connectors prevented the engine's radio from working, NTSB investigators found it to be functioning properly on January 11, 1987 when tested.

Ricky Gates further complained in his statement to the NTSB Hearing Board that the windshield of the lead unit was soiled obstructing his vision. Conrail procedures require reporting of such conditions. Although Gates maintained that he told this to Mince and got paper towels before leaving, Mince denies that he made such a report. In inspection of the engine after the collision, NTSB investigators did not take exception to the condition of the windshield.

### **CAB SIGNALS**

The location for conducting tests of the cab signal systems is the test rack on the lawn within the yard. In conducting tests, rules require that each aspect light when appropriate. In the event that a bulb is missing or burned out, replacement bulbs are available and easily installed. Operating rules require tests of both the lead and trailing engine in the event a reverse move is required. Pulse records indicate that the trailing unit was never tested. In subsequent questioning before the NTSB, Gates and Cromwell said they had tested both the lead and trailing units.

The cab signals and the warning whistle were tested with Gates seated inside the lead engine and Cromwell outside operating the four position switch that triggers the appropriate drop in signals. While Cromwell was outside at the circuit box, Gates rang a bell to acknowledge each position change. From his position outside on the ground, Cromwell was not able to see the signal or hear the whistle reaction in the cab. Cromwell concluded from Gates response that all signal systems were properly working. Yardmaster David Holstein conformed that Cromwell appeared to be conducting cab signal tests outside the unit.

Following the collision, NTSB investigators at the accident site entered the lead engine at approximately 10:00 p.m. At that time they noted that a bulb was missing from the approach aspect of the cab signal. The next day, NTSB investigators replaced the missing bulb and found the light functioned properly. In questioning before the NTSB on January 7, 1987, Gates maintained that all four aspects lit when tested.

On Monday, January 5, 1987, at 4:00 p.m., the NTSB Vehicle Factors Group conducted extensive testing of the lead unit, including the functioning of the cab signals and warning whistle. This group included Conrail

Superintendent Al Ray. Mr. Ray noted that upon dropping the signals, the whistle emitted no sound. After removing the panel cover and exposing the whistle, the investigators found that the whistle had been completely sealed with duct tape. The only audible sound was a faint hiss. Federal Bureau of Investigation (FBI) examined the tape for latent prints and found none. Further they estimated that the tape had been on for some time, but could not determine its age. Upon cutting open the tape with a pen knife, the whistle sounded loud and clear. In questioning before the NTSB, Gates maintained that during testing he did hear a whistle, albeit a faint one, when the signal dropped.

In summary, five failures occurred during preliminary testing: the failure to correct taped whistle, the missing bulb, the use of a yard portable when a properly functioning engine radio was available, failure to perform signal tests on the rear unit, and failure to test the brake system.

Gates did not report the apparent failures to supervisory personnel Mince or Holstein prior to departure as required. Had he reported them, he would have to undertake corrective measures which necessarily include a delay in his departure time.

### **TRACK ALIGNMENT FOR THE CONSIST**

Earlier in the morning of January 4, Train Dispatcher John Akins coordinated with Bay Tower Operator Milton Brown and Edgewood Tower Operator Rich Hafer all train movements through Bayview north to the "Gunpow" interlocking and beyond. Per Akins' instructions, Hafer aligned the tracks at "Gunpow" so that northbound passenger trains on Track 2 would have the right-of-way, thus holding up any northbound freight trains at the interlocking until passenger traffic was cleared. Since 10:30 a.m., the tracks and switches at the interlocking were set in this, the normal alignment. Akins instructed Hafer to allow the Amtrak 94 Colonial and 112 Metroliner, traveling five minutes behind the 94, through the interlocking before the Conrail consist.

This alignment meant that Gates' consist would be held up with a stop at the Home signal, the last wayside signal before entering the interlocking. He could only proceed after the Colonial and the Metroliner were safely through.

With the switch set at stop at the interlocking, the resultant wayside and cab signals for the defendant's consist on Track 1 was clear on cab and wayside from Bayview Yard up to the distant signal. This would have registered as an approach on both the wayside and cab signals as well as triggered the warning whistle. The second signal drop occurred at the Code Change Point, one mile from the home signal where cab signals dropped

to restricting and once again would sound the whistle. There is no corresponding wayside at the Code Change Point. At the home signal, stop appears on the wayside while restricting appears in the cab. The signals set for the Colonial on Track 2 were clear through the distant, the Code Change Point and home signals.

Post collision review of the event recorder data retrieved from the interlocking on January 4, 1987 at 5:00 p.m. revealed that all circuits and switches were properly functioning. Further, the track as well as corresponding signals were set as indicated by Tower Operator Hafer.

### **THE CONSIST DEPARTURE FROM BAYVIEW**

At 1:08 p.m. Gates communicated with Bay Tower Operator, Milton Brown, indicating he was ready to leave the yard. At 1:13 p.m., the tower cleared Gates to proceed to track number 1, which is the track commonly used for northbound freight trains.

At 1:15:30 the consist, engineered by Ricky Gates, came out of the yard and was traveling at 10 mph. By 1:18 Gates had the consist in throttle two and was traveling at 56 mph. At 1:20 he was on track number 1 at milepost 89 and had accelerated to speeds between 60 and 65 mph. He passed Stemmers Run at 1:21:30 maintaining his speed. He passed the Middle River signal at 1:23:30 and the Bengies signal at 1:25:30. The signals were clear and Gates was shifting between throttle 1 and throttle 2 in order to maintain a speed just over 60 mph.

As Gates reached the distant signal at milepost 81.6, the wayside signal was showing approach, requiring a reduction in speed to 30 mph. But for the missing light bulb, the cab signal would have also displayed approach. This would also be the first time the warning whistle would sound if it had not been taped. The pulse tape of the 5044 shows that Gates did not reduce his speed but continued at 60 mph at throttle 1. There was no brake application. The time was 1:27:30.

One minute and one mile later, Gates passed the code change point which dropped his cab signal to restricting, requiring a speed of 15 mph in preparation for a stop. This bulb was working, but the warning whistle was again inaudible. The pulse recorder shows that just as he passed that point, Gates did not brake or reduce speed, but in fact he shifted up to throttle 2 and slightly increased his speed above 60 mph. At this point, the consist was one mile from the home signal displaying a stop. No braking action or reduction in speed occurred for more than one-half mile until the Gates' consist was approximately 1,650 feet from the home signal. Only then did he apply the emergency brakes in an attempt to bring the train to a stop. The emergency braking started at 1:29 and concluded approximately 45 seconds later.

The consist has skidded 450 feet past the home signal. Because the switch was not aligned for the Conrail consist to proceed onto track 2, the consist broke the switch. The collision occurred fourteen and one-half seconds later at a point approximately six hundred yards from the Gunpowder River.

### SIGHT AND STOP DISTANCE TESTS

On Monday, January 23, 1987, sight and stop distance tests were conducted by NTSB and FRA investigators, as well as representatives of Conrail and Amtrak. Light and weather conditions were similar to those existing on January 4. From those tests, investigators concluded that Ricky Gates had more than sufficient time and distance to see the home signal and stop, using a normal brake application before entering the interlocking.

### THE COLONIAL — BAYVIEW TO GUNPOW

The Amtrak 94 Colonial, a consist of two electric engines number 900 and 903 and twelve passenger cars, left Washington, D. C., its point of origination at 12:50 p.m. On departure at 1:16 p.m. from downtown Baltimore, the Colonial was crowded with holiday travelers and students returning to schools in the northeast. Fortunately, at Baltimore, no passengers were allowed entrance on the first car in the consist which was reserved for additional passengers anticipated in Philadelphia and Wilmington. The second car contained 25 passengers; all other cars were full to capacity, carrying a total of 660 passengers.

At 1:25 p.m. Bay Tower notified Rich Hafer in Edgewood Tower that the Colonial was just passing on approach to the interlocking. Hafer responded correctly by giving the Colonial the planned clear signal through the "Gunpow". This did not require any change in track alignment; nor did it cause any change in signal on track 1, the track bearing the Conrail consist.

As the Colonial reached the distant signal at Chase and the subsequent code change point, its recorded speed was between 120 and 125 mph operating under clear signals. Ordinarily 120 mph was its maximum authorized speed. On this particular trip, its speed was restricted to 105 mph because of an older Heritage car in the consist. As the Colonial reached 2370 feet from the home signal, the clear signal ahead on the wayside dropped to a stop. This signal change was triggered by the Conrail consist's breaking the switch and entering track 2. Within seconds the Colonial's engineer, Jerome Evans, applied his emergency brakes in a futile effort to stop his engines before colliding with the consist. Evans attempted to jump from his cab within seconds of the

collision, however, he was unable to escape the explosive force of the impact and died instantaneously.

Records from the Colonial's speed recorder show that only fifteen seconds transpired between the time the signal dropped and the collision occurred. Evans applied the emergency brakes for eight seconds reducing the speed of the Colonial to 100-105 mph prior to impact.

Amtrak engines are designed to stop at 10,700 feet with a full service brake application at 120 mph and at 7480 feet for an emergency brake application. Although the 900 and the 903 were equipped with automatic braking systems, they were not activated because all signals up to the home signal were clear. Unquestionably, insufficient time and distance existed to allow engineer Evans to stop the Colonial before colliding with the Conrail consist.

### INSIDE THE CONRAIL CONSIST

On moving out onto track 1 out of the yard, Cromwell sat in the fireman's seat while Gates sat at the controls. Both faced forward. Gates called out the first two to three signals within one and one-half miles of the yard as clear and Cromwell acknowledged. Although Amtrak operating rules require that the engineer call each wayside signal and that the brakeman acknowledge, no more signals were called in the remaining nine miles. After the third signal, Cromwell pulled out a pin joint, a very thin hand-rolled cigarette containing marijuana, that he brought in his grip. Although he originally intended to use it on the ride home, Cromwell decided to smoke it then with Gates because the two smoked while working on one previous occasion. Each man had about three hits of the joint. Then Cromwell smoked the remainder in a pipe. Although both Gates and Cromwell were faced forward and could clearly see the wayside signals, neither called them while smoking the joint.

Next, Cromwell left his seat and turned facing the rear of the engine to make his lunch while Gates sat at the controls. With his back to the cab signals and the warning whistle taped, Cromwell was not aware of the signal change. He did not note any change or reduction of speed while fixing lunch until Ricky Gates threw the emergency brake.

As soon as Cromwell realized that Gates had thrown the engines into emergency, he looked out the window and saw that they were in the interlocking. Upon looking back through the rear window, Cromwell saw the headlights of the Amtrak Colonial headed in their direction on the same track. In that instant, Cromwell realized they had fouled track 2 and were about to be hit. Cromwell left the cab jumping from the engine on the eastside of the track just before the engines stopped. Gates remained on the engine until after the collision.

## THE IMPACT

The force of the impact between the Colonial weighing 1.6 million pounds, traveling at 105 mph and the stationary multi-ton Conrail consist defies description. The point of impact occurred 336 feet past the home signal at the switch from track 1 to 2. The Colonial's lead engine, the 903, struck the left side of the trailing Conrail engine, causing a tremendous explosion. The force of the impact propelled the two forward engines down the track approximately 700 feet and 900 feet respectively. Both remained upright but derailed.

The rear Conrail engine, 5045, was completely destroyed by the force of the impact. The barely recognizable remnants of this engine came to rest 300 feet at a 12 degree angle to the right of track 1. The lead Colonial engine was completely crushed up to its rear cab. This engine derailed and finally stopped on the westside between track 3 and Harewood Road. The 900 engine, also totalled in the collision, remained upright on track 2. The first three coach cars derailed, piling on top of each other. The first coach car containing no passengers was crushed and fragmented. The second and third cars were also crushed and further destroyed by explosion and fire resulting from the impact between the Colonial and Conrail engines. Fifteen passenger fatalities occurred in the second and third cars as well as the most serious injuries to the survivors.

All remaining Amtrak cars derailed. Cars numbered 4 through 9 remained upright but across the track. The tenth and eleventh derailed in line. The twelfth and final car derailed upright but tilted at a 45 degree angle.

## ENVIRONMENT AT POINT OF IMPACT

The four tracks leading up to and at the "Gunpow" dissect several small residential neighborhoods in two. Residences on either sides of the track are inhabited by many members of the railroad community. All of the homes are individual ones and most are owner occupied. The tracks often fall within one to two hundred feet in the homes of this community.

At the time of the collision, many residents were at home preparing Sunday dinner or watching football on television. The force of the collision knocked down one resident of Birdwood Road as she stood in the rear yard hanging clothes on the line within 250 feet of the collision. To many residents witnessing the collision, it felt as if an earthquake were occurring. The noise and force of the collision was felt several miles away.

Residents of many Chase homes immediately responded to assist in the rescue efforts. Several people ran to the site and assisted in quenching the flames that threatened to engulf the passenger cars. Others climbed

into the burning wreckage searching for survivors. Rescue efforts by these residents continued throughout the 4th and 5th of January and, in some cases, through the week. Most residents opened their homes to passengers, police and rescue squads.

## CONRAIL CREW POST IMPACT

Ricky Gates remained on his engine until it stopped. Once on the ground, overwhelmed by the wreckage, he contacted Edgewood Tower Operator, Rich Hafer, to advise him of the situation. Gates remained at the wreck site assisting in the rescue effort and searching for his co-worker, Cromwell, until his supervisor, Mike Chewar, sent him with Conrail Police to Franklin Square Hospital to provide blood and urine specimens for toxicological testing.

The brakeman, Cromwell, after jumping from the engine, was knocked down by the explosion on impact. On regaining his senses, Cromwell returned to the lead engine searching for Gates and his grip containing the pipe in which he smoked the residue of the joint. Upon retrieving the grip, Cromwell discarded the pipe in a nearby yard. He went to a neighboring home to use a phone to contact his fiancée, Mary Sattler, and to ensure that rescue help was on its way. Cromwell remained at the fire station near the scene until taken to Johns Hopkins Hospital by ambulance where he was treated for a fractured leg.

## RICKY GATES' ADMISSIONS POST COLLISION

On January 4, 1987, between 2:00 and 4:00 p.m., Christopher A. Strehlein, Safety and Environmental Control Engineer with Amtrak responded to the scene at Chase, Maryland. While at the scene, he came upon Ricky Gates whom he has known for about a year. Strehlein was surprised to see Gates since he had been led to understand that Mike Chewar, Conrail Superintendent, had requested that Gates go to the hospital for a blood and urine test. Strehlein called Mike Chewar on a portable radio who told him that Gates should go to the hospital. Gates refused, indicating he was not injured. Strehlein turned him over to Conrail supervisory personnel. While walking together in response to Strehlein's question concerning the cause of the collision, Gates stated it was pretty obvious; that, in his words, "he fucked up", "he got by a couple signals." Strehlein did not detect anything unusual about Gates' condition which would indicate lack of sobriety.

On January 4, 1987, at about 2:30 p.m., Mike Chewar, then Internal Superintendent for Conrail in Baltimore, Maryland, arrived at the accident scene. Chewar

questioned Gates about the cause of the accident and he responded, "I got by the stop signal, got out on #2 track and got hit by a passenger train."

Russell C. English, Baltimore County Fire Department Medic Unit Driver, also encountered Ricky Gates at 2:10 p.m. near the damaged Conrail engines. Gates acknowledged to English that he blew a "red" or stop signal and was unable to reverse back to his track. Although Mr. English observed nothing to indicate a lack of sobriety, he did note that Gates went limp from relief when his radio was taken from him.

The next statement from Ricky Gates was taken by Henry Payne at 7:30 p.m. on January 4. Gates claimed he received a less restricted signal at the distant wayside than actually displayed. Although Gates claimed to reduce his speed at this point, pulse records show that not only did he fail to reduce speed, but also Gates increased speed by throttling up one notch. Furthermore, he claimed the warning whistle, subsequently found taped, tested properly during pre-departure tests.

#### **GATES' DRUG TEST**

At approximately 4:00 p.m. on January 4, 1987, Trainmaster Henry Payne located Ricky Gates walking along the eastside of the accident site. Payne brought Gates to Mike Chewar, Terminal Superintendent, and Edwin Beyer, Captain of the Conrail Police Department. Chewar then instructed Trainmaster George Mince and Captain Beyer to take Gates to Franklin Square Hospital for treatment and to have a toxicology test sample drawn. Gates was again advised by George Mince that FRA rules require that he submit to a toxicological screen of his blood and urine. Samples of both were obtained from Gates, packaged, sealed and sent to the FRA CAMI Laboratory in Oklahoma City for analysis.

The results of the toxicological analysis by CAMI for Ricky Gates, indicated the presence of Marijuana THC, a Schedule I, non-narcotic controlled dangerous substance, in both blood and urine samples tested using two different quantification techniques. Tests for all other drugs in the protocol were negative. The urine sample was then sent by CAMI to The Center for Human Toxicology at the University of Utah pursuant to the NTSB's request due to irregularities at CAMI not affecting this case. Again the presence of Marijuana THC was confirmed; all other drugs were negative.

Expert witnesses who have reviewed the levels of marijuana in Gates' blood and urine have been unable to render an opinion regarding impairment.

A blood sample taken from Gates by Franklin Square Hospital for medical diagnostic purposes was screened for alcohol and drug use and showed less than 10 milligrams or less than .01% blood alcohol level. The Franklin

Square Hospital test was negative for all other drugs, including cocaine metabolites and PCP. Franklin Square Hospital, however, does not test for marijuana THC or its derivatives.

#### **GATES' CONDUCT BEFORE THE NTSB**

Edward Cromwell was hospitalized from January 4th to January 6th, 1987 at Johns Hopkins Hospital for a broken leg.

On the morning of January 6th, Mike Chewar, the Terminal Superintendent for Conrail, and Larry Jones, the Road Foreman for Conrail, visited Cromwell at the hospital. The purpose of the visit was two-fold; first, to inform Cromwell that he was being removed from Conrail service and to serve him with a written notice to that effect and secondly, to have Cromwell respond to questions presented by Chewar.

Mr. Cromwell truthfully responded to the questions informing Chewar of the following information. First, there was only one cab signal test performed on the consist by him and Gates. Second, the signals at Point and River were clear and that he did not know what the signals were at Chase and "Gunpow". Cromwell explained that he was occupied fixing his and Gates water bottles for their lunch, that his back was turned to the cab signal and that he could not remember calling any signals. He further stated that the first knowledge he had of any trouble was when the train went into emergency. At the hospital, Cromwell also spoke with Union Representatives, H. A. (Bud) Daugherty and M. W. Packer, Jr., and advised them that he did not know what happened.

When Cromwell was released from Johns Hopkins Hospital on January 6th, he went to his home at 3917 Bayville Road in Baltimore County. On the night of January 6th, Ricky Gates went to Cromwell's house to discuss the next day's hearing before the NTSB. Present at the home was Mary Sattler, Cromwell's fiancée.

At that time, Gates wrote down for Ed Cromwell what was to be his account of the accident. Maryland State Police handwriting expert, Lt. Gary Girton, examined this writing and concluded that Gates wrote it. Cromwell agreed he would testify in this manner at the hearing the next day. When Gates was discussing the cab signal, Cromwell told him that he had not seen it. Gates told Sattler and Cromwell that the NTSB would not see it that way. When Sattler told Gates that he was the one driving the train, not Cromwell, Gates replied that NTSB will not see it that way. Ricky Gates also discussed what they would say to make the wayside and cab signal coincide. Sattler asked Gates what did happen. He responded, "I messed up."

The story Gates wrote for Cromwell was the one which Cromwell subsequently told to the NTSB. At the

meeting with Gates on January 6, 1987, according to Cromwell, he asked Gates if he had told anyone about the marijuana. Gates said he had only told Bud Daugherty, his BLE Union Representative. According to Ricky Gates' account of this conversation, Cromwell asked to whom he told everything and he responded it was only Bud Daugherty.

On January 7th, the NTSB held a hearing in Baltimore City. Participating in the hearing were members of the NTSB, FRA and Union Representatives, including H.D. (Bud) Daugherty. The purpose of the hearing was to obtain testimony from engineer Gates and brakeman Cromwell.

Cromwell's testimony included the statements that both front and back cab signal tests, as required, were

done on the Conrail consist and that at the Chase signal (the 81.6 milepost), Gates called approach limited and Cromwell looked at the cab signal and saw an approach medium. Both statements about tests and signals were untrue. Cromwell also told the NTSB that he had not used drugs the day of the crash. That statement was also false.

Ricky Gates also testified at the NTSB hearing and stated he had performed the two required cab signal tests on the consist and that he had an approach limited on the wayside signal at Chase and a corresponding approach medium in the cab. He further told the hearing board that Cromwell had seen approach medium on the cab signal at Chase. When asked if he had used drugs on the day of the accident, Gates responded that he had not.

## MASS DISASTERS OCCURRING IN A SCHOOL BUS

*George R. Nichols II*

Kentucky State Medical Examiners Office  
Louisville, Kentucky

At 10:55 p.m. on Saturday May 14, 1988, a four wheel drive 1987 Toyota pickup truck crossed the median of I-71 traveling northbound. The pickup truck driven by Larry Mahoney collided with a southbound 1977 Superior Bus mounted on a Ford chassis. The bus, carrying 67 child and adult passengers (legal capacity) was rapidly aflame. Fire quickly consumed the bus whose front door was disabled by the crash, limiting escape for the passengers to a single rear safety door and passenger windows. Twenty-four children age ten through nineteen and three adults perished, making this tragedy the second worst bus disaster in U. S. history, and the greatest number of fatalities as the result of a drunken driver.

The site was adjacent to the median of a major interstate highway in rural Carroll County Kentucky, approximately 58 miles from Cincinnati, Ohio. The injured living victims had been removed from the scene prior to our arrival at approximately 12:25 a.m. on May 15, 1988. No local morgue was available. The nearest available morgue was in Louisville, fifty-four miles distant. The vehicle was still too hot to enter beyond the rear door at that time. Preliminary survey from that vantage point demonstrated at least eighteen commingled and incinerated human remains to be visible.

In consultation with the County Coroner, State Police and Disaster and Emergency Services, a decision was reached to move the scene. Additional agencies involved, subsequent to this decision, included the Kentucky National Guard, Kentucky Department of Highways, American Red Cross and Carroll County Disaster Squad. A crane and "low-boy" trailer attached to a tractor rig were brought to the site. After daybreak the scene (the bus) was loaded onto the trailer and taken to a temporary morgue housed in a National Guard Armory on the outskirts of Carrollton, KY, an approximate five mile trip.

Equipment and personnel to conduct a bus post-mortem examination was assembled from varying agencies. The initial team included one forensic odontologist, one forensic autopsy technician, one forensic pathologist and one motor vehicle collision reconstructionist. Other disaster personnel from many agencies had assembled at the temporary morgue by the arrival of the entire disaster team at approximately 9:00 a.m. on May 15, 1988. The temporary morgue was not air conditioned. The forecast high temperature was 29°C. Disas-

ter pouches, stretchers, portable air conditioners, refrigerated tractor trailers, communications systems and autopsy equipment were brought to the morgue from varying sites including Louisville, Cincinnati, Frankfort, St Luke's Hospital in Alexandria, KY, and the Greater Cincinnati Airport.

Family members, some of whom spontaneously arrived at the morgue, were diverted to a Red Cross staffed holding station at a local motel. Interviews with family members were conducted at this site and also simultaneously in Radcliffe, KY, the home of the First Assembly of God Church where the outing to an amusement park had originated.

Initial in-vehicle examination by the four members of the disaster team began at approximately 10:00 a.m. Entry to the bus was made through both front and back doors. It was apparent that an unknown number of victims were commingled and incinerated in the seat rows seven, eight and nine. Their bodies in some cases were stacked as to create a functional blockage to further inspections.

Discussions were held between the disaster team and officials from varying agencies as to which extrication method should and could be employed to safely remove the bodies and not create factitious damage to their remains. Suggestions included removal of the side walls of the bus (extremely impractical without the necessary cutting devices and clearly damaging to evaluation of structural damage to the bus), removal of the seat bolts from the undercarriage of the bus (physically impossible due to wear of the bus and generalized rusting of the belts) and the use of the "jaws of life" to sequentially remove the seats from aft-forward into the bus.

As an aside the narrowness of the aisleway between the eleven rows of bench seats must be stressed. The aisle was approximately 30 cm wide. This factor, complicated by the commingling and stacking of the victims bodies and the severe degree of incineration was the determining factor as to the most appropriate available personnel to physically remove the bodies. In the usual disaster, the victims are generally removed by the "big guys" — the police, the firemen, the emergency medical personnel. They were simply too large physically to process the scene without producing unintentioned secondary trauma to the bodies. The primary extrication team was determined to be a pathologist, an odontologist

and an autopsy technician. The largest member of this team was five feet nine inches in height.

Before extrication began the internal scene within the bus was independently examined by the pathologist, the odontologist and the motor vehicle collision reconstructionist. The bus was sketched separately by the reconstructionist and the odontologist. The findings were dictated into a tape recorder by the pathologist.

Prior to victim removal, a conference was held between the disaster team and pastoral representatives of the families. During this event, two clergymen were allowed controlled internal access to the morgue. There, the ministers were shown the exterior of the bus and given a floor level view of the interior of the bus from the rear door. It was their immediate conclusion that the families should not view the remains of the victims. The chaplains then removed themselves to meet with the family members.

Prior to removal of rear rows of seats with the "jaws of life" the disaster team re-entered the bus in attempt to determine the number of bodies in place. This effort was electively terminated due to the requests for information from the assembled family members and the media.

The pathologist traveled one mile to meet with the families. Most, if not all of them, held out hope that there were less than 27 bodies on the bus. Somehow, they prayed that their son, daughter, wife or husband had escaped injured but unaccounted for though the effective triage, referral and transport system which had served the injured survivors. The preliminary and independent census from each of the disaster team members was 25 victims. The pathologist advised that an actual number of victims would be determined as soon as possible and that this information would be conveyed to the families immediately. Lastly, the pathologist denied all requests to view the victims admonishing the parents to remember their children as they were pictured in their wallets.

Returning to the morgue, the clamor of the press was of pressing concern. An initial press briefing was undertaken. Press interviews were regularly scheduled thereafter.

The last two rows of seats were then removed. The traffic reconstructionist and pathologist again conducted independent censuses. Each concluded that the number of victims was 27. This information was conveyed to the families via the chaplains. Then the body removal process began.

Each body was charted and photographed in group and *in situ*. The remains were removed sequentially and their bodies were given chronologic numbers which would remain their standard until identification was confirmed.

The bodies were placed in numbered disaster pouches and in turn put on stretchers arranged along the

right side of the bus. As equipment arrived, they were placed into refrigerated tractors for storage prior to post mortem examination.

Autopsies were sequentially performed along the left side of the bus. The dental identification process (both ante and post mortem) was ongoing simultaneously. The entire disaster team eventually was composed of one autopsy technician, four odontologists, one pathology resident, two forensic pathologists, one motor vehicle reconstructionist, one medical examiner administrator, one coroner, multiple deputy coroners and members of the Kentucky National Guard, Kentucky State Police and the Carroll County Rescue Squad.

Upon completion of examination, the numbered remains were returned to storage in refrigerated tractor trailers.

The post mortem examinations were concluded at 8:30 p.m. on Sunday, May 15, 1988.

The dental identification concerned 27 victims all burned beyond visual recognition. Twenty-four were children, most between 11 and 14 years of age. Two-thirds of the victims were female.

Sixteen antemortem records arrived via U. S. Army helicopter from Ft. Knox, KY, on Sunday, May 15, 1988. Six civilian records were received within several days. One retired military record was received on Monday, May 16, 1988 from St. Louis. Dental records were unavailable on four persons but two of those had positive anecdotal dental information provided via Red Cross from the family.

Four dentists processed and analyzed the dental data. Two dentists resected jaws and placed them in numbered containers of formalin. One dentist served as the "postmortem section", charting findings on an odontogram. One dentist served as the "ante-mortem section", converting antemortem data to an odontogram in similar fashion. Within 9 hours (36 man hours) this work was completed.

Five distinct triage groups were formed:

- 1 — Those with many fillings (4).
- 2 — Children with adult dentitions with few fillings (7).
- 3 — Children with adult dentitions and no fillings (8).
- 4 — Children with orthodontic appliances (4).
- 5 — Children with mixed dentitions (4).

At the termination of Sunday's work, all antemortem charts could be tentatively matched to a corresponding post-mortem chart. Other bodies upon whom dental evidence had not yet been received were also tentatively identified by exclusion or personal effects. This work was done rapidly and without computers.

On Monday, the second working day, the labelled specimens and dental records were formally matched

using radiographic, study cast and photographic methods when necessary to confirm an identification. This process required two dentists working ten hours each. There were no initial errors in the initial matchups.

The results: 23 positive dental identifications, 2 positive identifications made from combined evidence, and 2 identifications made by personal effects and exclusion.

Certain factors facilitated the identification effort: 1) no impact injury or scattering, 2) the relative small number of disaster victims and personnel, 3) adequate quantity of quality antemortem dental records expeditiously recovered from a single repository, and 4) a known and trustworthy manifest.

Other factors impeded the identification process: 1) extreme charring, 2) entrapment of victims around bus seats and each other complicating removal, 3) close quarters, poor lighting and fixed objects, 4) dental similarity of victims with no or few fillings, 5) rapidly changing dentition of children, 6) unescapable nature of human tragedy since the scene was so well preserved (Bernstein et al. 1990).

The identification process (primarily odontologic) was completed at 5:30 p.m. on Monday, May 16, 1988.

The 27 victims were found from the drivers seat to row nine of the bus. The adults (youth minister, driver and chaperoning mother) were found in the drivers seat, right seat row five and left seat row six respectively. The children were recovered in row four aisle (1); row five aisle (1), row six aisle (2) right seat (1); row seven aisle (1) and right seat (5); row eight aisle (1), right seat (4), left seat (2); row nine aisle (3), right seat (3).

The cause of death in each case was determined to be smoke inhalation with perimortem thermal injury. There was no evidence of crash impact resulting in internal injury or observable orthopedic abnormality.

Carboxyhemoglobin determinations were performed in each victim using visible spectroscopy and microdiffusion confirmation. The results display a ran-

dom distribution of levels from 18-69% saturation of hemoglobin and appear in Table 1. The concentrations were 29.6% at 50% or greater, 55.5% at 40% or greater and 74.1% at 30% or greater. The mean of all samples was 41.9%.

Blood cyanide screening was performed by Prussian blue methodology (with a published sensitivity of 5 µg/ml) (Kaye 1973). One test was reported as positive at the level of detection. This fatality was in row five.

Serum drug screening (by thin layer chromatography, gas liquid chromatography, enzyme multiplied immunoassay, and fluorescence polarization) and blood alcohol testing (by gas liquid chromatography) were performed on each adult. Each test was negative.

Blood alcohol testing (by gas liquid chromatography) was also performed on all children. Four samples were reported as positive. The detected levels ranged from 0.03 to 0.28% weight/volume. The lower three positives (0.03, 0.09 and 0.10%) remained stable at repeated testings. The highest level, 0.28%, was retested on six occasions in the next two weeks. The level reached 0.95%. The glucose of the sample was measured at 860 mg/dl. Cultures of the sample grew alpha Streptococcus and Staphylococcus epidermidis.

In each case in which a positive blood alcohol was obtained, the body position was prone with the abdomen in tight contact with the bus floor.

The post mortem examinations and later family interviews demonstrated that eight of the child victims had significant past medical histories which ranged from asthma requiring medication (6) to surgically corrected congenital heart disease (1) and active cystic fibrosis (1). As with the victims as a whole, this group also displays extreme variability of carboxyhemoglobin levels ranging from 26% to 69%: 20% (2), 30% (3), 40% (0), 50% (2), 60% (1) with the mean 42.6%.

The bodies were embalmed on Tuesday and they were released on Wednesday, May 18, 1988.

In conclusion, the events of this mass disaster were processed in such a fashion as to move the scene. This decision allowed better scientific evaluation and controlled access in a rural scene.

**Table 1. Carboxyhemoglobin determinations from victims of bus crash.**

Carboxyhemoglobin Levels (%)	Number of Victims
18	1
20-29	6
30-39	5
40-49	7
50-59	6
60-69	2

Mean of all samples 41.9%

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# **APPLYING FORENSIC ANTHROPOLOGY TO HISTORICAL PROBLEMS: A REVIEW OF RECENT INVESTIGATIONS INTO THE THIRD FRANKLIN ARCTIC EXPEDITION**

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Most North American forensic anthropologists began their careers in university programs in anthropology or archaeology and received training and experience through the analysis of human skeletal remains recovered from archaeological sites. This is a branch of anthropology called physical (or biological) anthropology. As natural extension of these acquired abilities and research skills, physical anthropologists are regularly called upon by police and government agencies involved in modern human death investigation. The specialization called forensic anthropology has evolved from this relationship.

Forensic anthropology has many definitions, but most researchers agree that the common goal of the discipline is to provide information which can lead to the establishment of the identity of unknown human remains within a medico-legal context. In cooperation with other forensic scientists, the forensic anthropologist can also contribute in the determination of the circumstances leading to the death of an individual or individuals. In addition to the evaluation of age at time of death, sex, ancestry, individualizing features, and elapsed time since death (among other information), the forensic anthropologist usually has access to forensic laboratory facilities run by state, provincial, and federal agencies, or other laboratories at universities or in the private sector. These facilities allow for the expansion of the information gathering process into the areas of bone micromorphology, microbiology and biochemistry.

Completing the cycle, the experiences and research of the forensic anthropologist can also benefit the analysis and interpretation of archaeologically derived human remains, and the results of some of this research is regularly reported in the forensic sciences journals. The *Journal of Forensic Medicine and Pathology* contains section titles "Forensic History" and "Forensic Anthropology" where forensic anthropologists and other forensic scientists assess the crimes and/or deaths of historical figures within a historical context. The *Journal of Forensic Sciences'* "Last Word Society" similarly considers matters of historical archaeology, and a number of books and monographs on historic and prehistoric archaeological sites or on forensic sciences in archaeology have contributions from forensic scientists (for example,

Boddington *et al.* 1987).

Forensic science is now a common component of many archaeological projects. The value of this cooperation is considerable: it adds a highly credible source of information and interpretation through the detailed and methodical assessment of physical evidence. Our interpretations of history can be clarified or even changed altogether by the results obtained through this team approach, though the significance of the contributions made by the forensic scientist in archaeological studies is dependant on a number of conditions, including:

- 1 — the accuracy of the historical data derived directly from archival sources or interpretations made from these sources;
- 2 — the availability of the artifact and/or human materials for study;
- 3 — the ability to establish provenance with certainty for the artifact and/or human remains;
- 4 — the degree of preservation and/or disturbance of the physical evidence;
- 5 — the ability or lack of ability to establish identity for historical figures from available biographical data;
- 6 — ethical considerations regarding the excavation, recovery and analysis of human remains.

The research reported in this paper involves the archaeological and forensic investigations of a 19th Century mass disaster: the third Franklin Arctic expedition. All six of the listed conditions played some role in the degree to which we could provide a new perspective on this important and intensively studied historical event.

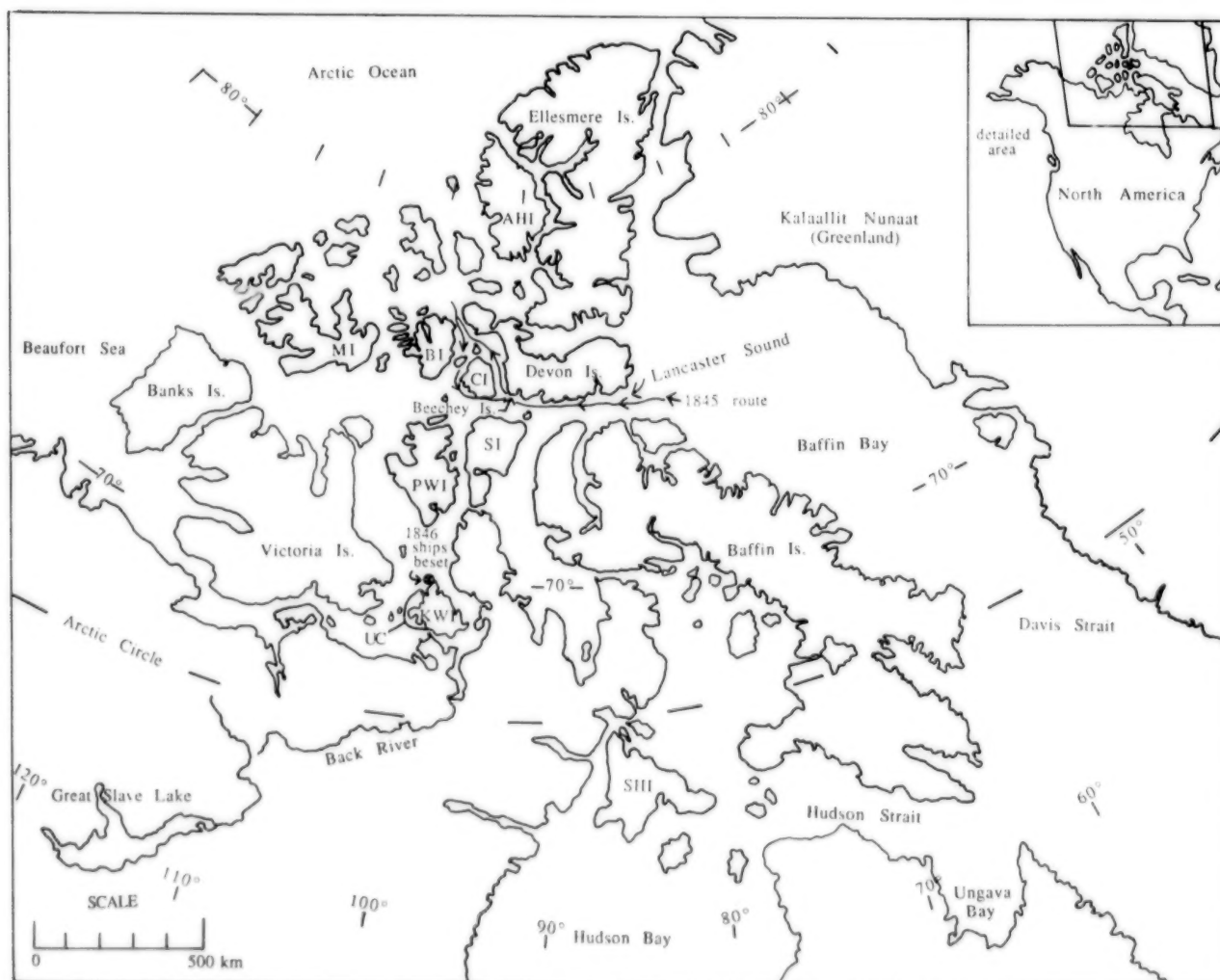
## **THE THIRD FRANKLIN EXPEDITION: HISTORICAL BACKGROUND TO A MASS DISASTER**

By the beginning of the Nineteenth Century the centuries-old search by Europeans for a Northwest Passage was at last thought to be achievable (for a thorough discussion and review of the topic see Cyriax 1939; Neatby 1970; Beattie and Geiger 1988). In the earlier period of this quest the motives for discovering a pas-

sage were primarily economic. The rich markets of the Pacific were the goals of these first explorers. By the early years of the 1800's it was realized that the costs in lives, ships, and resources were too great to justify or support the Northwest Passage as a trade route. The final expeditions in search of the Passage would be for national pride and scientific exploration. By the 1840's large areas of the Arctic had already been explored, though no European ship or person had been able to pass through this territory from either east to west or west to east, nor had a continuous route been linked over the years that should be called a Passage. In some areas as short a distance as 90 km remained to be explored and mapped to establish a complete Passage (Map 1). With the completion of the Northwest Passage so close at hand, the British mounted a final expedition that would accomplish what had taken so many years to piece together: the final charting of the Passage, and the sailing through the Passage from east to west. In May of 1845

two ships, HMS Erebus and HMS Terror (small Royal Navy warships, converted for Arctic service, and weighing 370 and 340 tons respectively), set sail from England in pursuit of this goal. Each ship was equipped with a steam engine that turned a screw propeller, marginally supplementing the sail power. On board the ships were 129 men and supplies for at least three years of isolation in the Arctic. Leading the expedition was a 59 year old veteran of Arctic exploration, Sir John Franklin.

Though many of the men had not seen Arctic service before, all were well aware of the dangers, hardships, and isolation that awaited them. Exploring the Arctic by ship was a challenging endeavor. The waters separating the islands were known to be frozen solid for ten or more months of the year, leaving a short two month sailing season. Therefore, the ships were expected to be locked in ice (beset) for 10 months at a time — conceivably a total of 30 months over the length of the expedition. Under these conditions the dangers were



Map 1. Map showing the Arctic Islands and the route of Franklin's expedition. Abbreviations: BI: Burthurst Island; CI: Cornwallis Island; KI: King Island; MI: Melville Island; PWI: Prince of Wales Island; SI: Somerset Island; UC: uncharted coastline of King William Island.

considerable, and if anything went wrong there was no way of getting word out to arrange a rescue. The weather was unpredictable and harsh, and during the winter months there was virtually no sunlight.

The two ships were last seen by Europeans in Baffin Bay in July of 1845 making towards Lancaster Sound, the eastern entrance to the Passage. Unfortunately, no rescue arrangements had been made for the expedition prior to sailing. By 1848 there had been no word of the expedition, and some concern was voiced in England for the safety of Franklin and his men. Beginning in that year, and continuing literally to the present day, search expeditions have gone into the Arctic to try to locate sites from Franklin's expedition and establish what went wrong. The first expeditions were for rescue, but they failed to find evidence of the lost expedition. In 1850 the first signs of the expedition were found on Beechey Island, a small island attached to the southwest tip of Devon Island. Franklin and his men spent the winter of 1845-6 at this site. During that period at least three men died, and were interred on the Island. Where they went next remained a mystery until, in 1854, Inuit reported the final details of the disaster in the area of King William Island, 600 km south of Beechey Island. In 1859 a search expedition sent to King William Island found evidence (artifacts, skeletons, Inuit account) that most of the men perished along the coast of King William Island, though the two ships were not found (M'Clintock 1908). Also discovered by this expedition in 1859 was a note from Franklin's expedition left in a tin canister under a pile of rocks on the northwest coast of the Island. Many of the known details about the disaster are derived from this note, and some of these are as follows (M'Clintock 1908):

- 1 — when the ice broke in the summer of 1846 the ships sailed south to a point approximately 25 km off the northwestern coast of King William Island where, in September, the ships again were beset;
- 2 — in May of 1847 a small group of men visited the west coast of King William Island;
- 3 — on June 11, 1847 Sir John Franklin died;
- 4 — on April 22 of 1848, with the ships still beset (they had not been released during the summer of 1847) 105 surviving crewmen deserted the two ships;
- 5 — their plans over the next weeks involved heading to the mouth of the Back River over 250 km to the southeast of the ships; it is presumed that they were planning to travel the river system into the Arctic tundra, eventually arriving at an Hudson's Bay fort on Great Slave Lake, a total distance of over 1200 km.

The discoveries of the 1859 search, and many later searches indicate that the last men died only a few hundred kilometers from the ships, probably in the late summer of 1848 (Gilder 1881; M'Clintock 1908; Nourse 1879; Stackpole 1965). This was the best equipped and manned expedition yet mounted by the British, and its loss was a stunning blow. How could it have failed? The explanation for the disaster has centered consistently on starvation and scurvy as the causes. Though they undoubtedly played some role in the disaster, some researchers feel that other factors were involved (see Beattie and Geiger 1988).

In 1981 and 1982 I had the opportunity to conduct an archaeological survey of part of the location of the disaster in the King William Island area. My primary motives were to locate, document, and analyze the human skeletal remains of some of the sailors whose bones had been seen by previous searchers. Most earlier searches had been concerned with the futile attempt at finding written documents from the expedition, or even the log books, hoping that they would contain information that would fill in the huge gaps in the understanding of the disaster. Though human remains were found by these searchers, they were considered as incidental, though tragic discoveries that could not contribute significantly in illuminating the larger picture of the expedition's loss. Following our discoveries in 1981 and 1982 circumstances led me to propose the investigation of the three sailors buried on Beechey Island, and known to be in permafrost. This was accomplished in 1984 and 1986.

A review of the results and the on-going research of these recent investigations are outlined in the following sections.

## FIELD WORK AND RESULTS, 1981 AND 1982

During the summers of 1981 and 1982 I conducted archaeological foot surveys of the west and south coasts of King William Island. These areas marked the route that the surviving Franklin expedition crew members took after deserting the ships in 1848. All of the human remains and artifacts discovered during the surveys were found on the surface.

Thirty-one bone fragments from a single individual were discovered in 1981 at the southeastern end of the island (Beattie and Savelle 1983). They were found in association with the remains of a tent structure used by a small group of Franklin expedition crew members very near the end of the disaster, and probably in the summer of 1848. The materials consist of lower and upper limb and skull fragments. The distribution of the bones, and the presence of cut marks on the posterior shaft of the right femur, have been attributed to cannibalistic activities (Beattie 1983). This observation corroborates the

reports of Inuit who visited many of the expedition's sites shortly after the end of the disaster. At this distance from the ships, and after having walked for many weeks, the sailors would have depleted their own supplies. Unable to support themselves from the land, starvation eventually became a reality. The long bones also possessed periosteal lesions that may be the result of scurvy. Certainly, by the third year of the expedition vitamin C deficiency would have been a factor in the declining health of the men.

In 1982, at a site on the west coast of the island, 29 bones and fragments representing the scattered remains of another six to fourteen sailors (minimum/maximum estimate) were discovered (Beattie 1983). These men had been associated with a lifeboat from one of the ships. This lifeboat had been found in 1859 with the skeletons of two sailors resting inside. Today only wood chips, bones, and a few artifacts remain to mark the location of the site. The long bones from these materials also have periosteal lesions possibly caused by scurvy. Stature estimates for these men range from 162 to 165 cm.

The human skeletal remains discovered in 1981 and 1982 were collected and returned to Edmonton, Canada, for additional analysis. One of the studies carried out on the materials from 1981 was analysis of the bone by inductively coupled plasma atomic emission spectrometry (ICP-AES) (Beattie 1985). Unexpectedly, a very high level of lead (125 µg/g dry weight) was found. Though there was some evidence for postmortem environmental effects on other element contents (specifically, aluminum levels were high), the lack of significant levels of lead in the surrounding sandy soil indicated that the lead was intrinsic to the bone (Kowal *et al.* 1989).

Discovering such a high amount of this toxic heavy metal raised a number of questions regarding the potential deleterious physiological and neurological effects that could have resulted from exposure to lead. Could this discovery provide a new and different insight into the circumstances leading to the loss of Franklin's expedition? The most important of the questions raised included:

- 1 — was the lead coming from sources on the expedition, or did the bone lead detected in the analysis originate from a period in the life of the sailor prior to the expedition?
- 2 — what were the sources of lead on the expedition? prior to the expedition?
- 3 — could the potentially devastating effects of lead on the behavior and mental capabilities of the men, especially the officers (the decision-makers), have played a role in the disaster?

With the small number of bones discovered in 1981 and 1982, the realization that little now remains in the King William Island area to discover, and the detection of lead in the bones, the decision was made to propose the investigation and analysis of the three Franklin expedition sailors buried in permafrost at Beechey Island. It was felt that the pervasive permafrost in this area of the Arctic would have provided an ideal situation for the preservation of uncontaminated human and artifact materials. One of the difficulties in the analysis of lead in bone tissues is the long residence time for the metal — some or even most of the lead detected in the sailors could have come from years of exposure prior to the expedition. If soft tissues could be found (representing a much lower residence time for lead) it would be possible to establish the significance of the exposure during the period of the expedition.

#### **FIELD WORK, 1984 AND 1986, BEECHEY ISLAND, NORTHWEST TERRITORY**

The excavation and sample collection on Beechey Island took place during the summers of 1984 and 1986. The grave site at the island is well marked, though the headboards standing there today are fiberglass replicas of the originals (Figure 1).

The three graves are lined up side by side and parallel to the shoreline. The grave closest to the shoreline is John Torrington's. He was a petty officer on HMS Terror, and died on January 1, 1846, age 20 years. The middle grave is John Hartnell's. He was an able-bodied seaman on HMS Erebus and he died on January 4, 1846, age 25 years. The third grave is William Braine's. He was a Royal Marine private on HMS Erebus and he died on April 3, 1846, age 33 years.

#### **1984 Season Field Work**

After the site was mapped and gridded for spatial control, excavations began on Torrington's grave. Permafrost was reached at 10 cm below the surface and intensive pick and shovel work was required to complete the excavation. At 1.5 m below surface Torrington's coffin was exposed. Careful cleaning revealed that the coffin was covered in blue wool material, and a hand-painted sheet metal plaque had been nailed to the lid (Figure 2). When the lid was removed we found that the inside of the coffin was filled with ice. Evidently, the summer runoff water of 1846 had trickled down through the original grave excavation, flowed into the coffin, and froze. We thawed the ice by applying cool and warm water. As the ice melted the preserved clothing and body of John Torrington became visible (Figure 3 a,b,c)

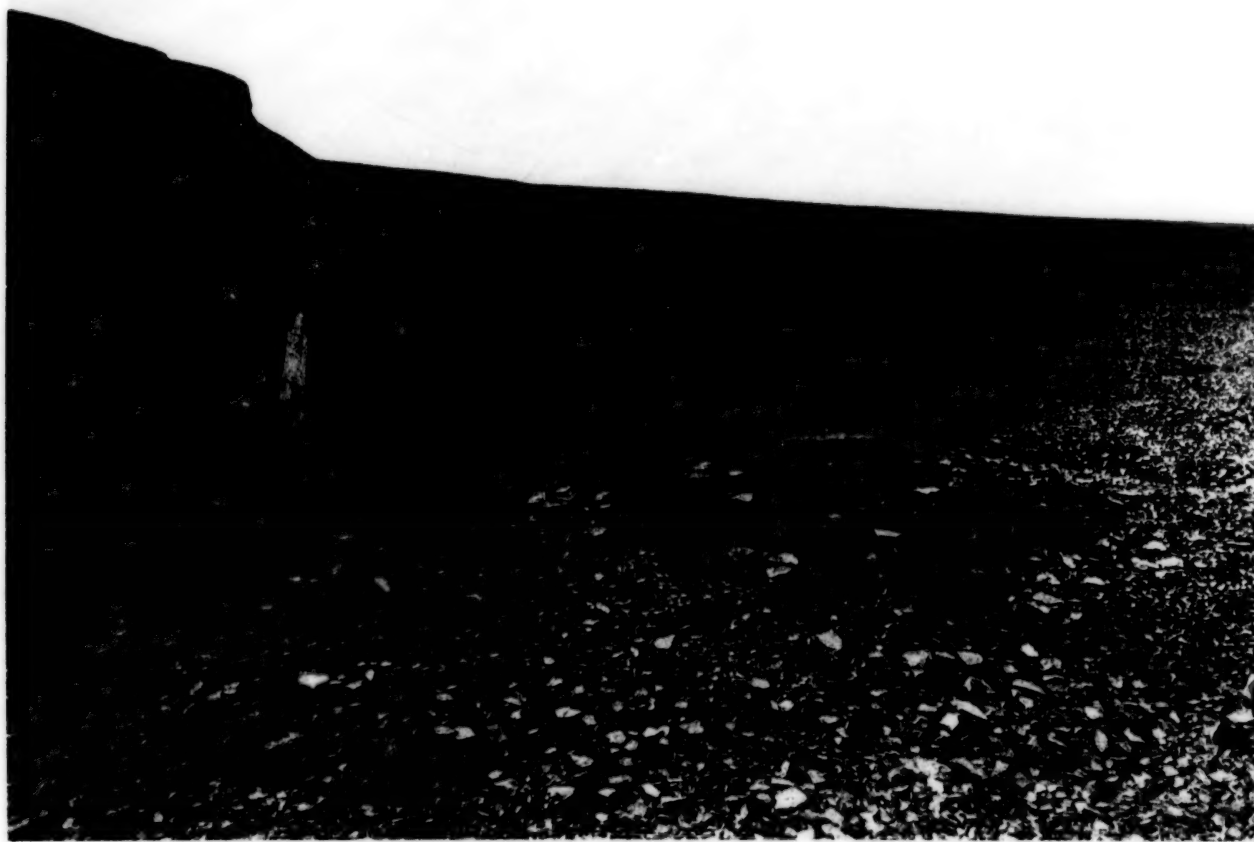


Figure 1. The Beechey Island grave site. The graves are those of (from right to left) John Torrington, John Hartnell and William Braine.

After removal of the ice, photographs and descriptions were made of Torrington's body. He was clothed in shirt and trousers. His feet were bare, and his kerchief was wrapped around his chin and knotted at the top of his head. In preparation for his burial he had been bound tightly with torn cotton strips. Though he was in a remarkable state of preservation, slight dehydration of the eyelids and lips could be identified (Figure 4). Otherwise, he looked as if he had just died.

Torrington was then lifted out of the coffin and positioned on a plastic ground sheet. He measured 162.5 cm long and weighed less than 40 kg (Amy *et al.* 1986). The clothing was removed and a four hour autopsy was conducted. During the autopsy all tissues and organs were still in a frozen state and had to be thawed with water. Samples of all tissues and organs were collected for more detailed analysis back in Edmonton. After the autopsy, Torrington's body was re clothed and placed back in the coffin. After repositioning of the body, the lid was replaced and reburial completed immediately, including the exact reconstruction of the surface details of the grave. During the whole process of exposure, autopsy, and reburial the air temperature was at 0°C, and

the temperature within the grave itself was much colder. The refreezing process began during the reburial, and the body was probably completely frozen within a few hours.

Excavation difficulties and the advancing season dictated that the remaining two individuals would have to be investigated in a following field season.

#### 1986 Season Field Work

Our excavations in 1986 followed much the same pattern as in 1984, though there were more on-site investigators. Additions to the research team included a radiologist and radiology technologist. Their responsibilities were to complete and process a full series of radiographs of Hartnell and Braine. The portable x-ray unit was powered by a small generator, and the films were processed immediately in a make-shift darkroom.

The 1986 excavations were conducted in June, and temperatures regularly dipped to -15°C. Excavation of the graves and thawing of the coffins and bodies was much more difficult than it had been in 1984.

The grave of John Hartnell was excavated first. The coffin was discovered at 0.85 m below the surface.

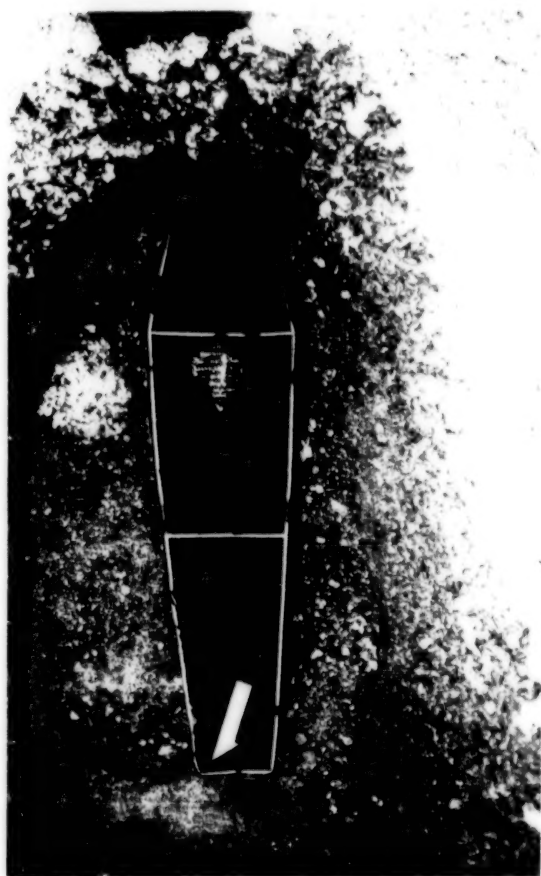


Figure 2. John Torrington's coffin. The plaque reads: John Torrington died January 1 1846 aged 20 years.

Prior to the 1986 season I learned from archival sources that Hartnell's grave had been excavated in September of 1852 by one of the search expeditions looking for Franklin (Inglefield 1852; Beattie and Geiger 1988). These searchers had badly damaged the coffin lid during the excavation (Figure 5). Also, one of the excavators had penetrated through the lid with his pick-axe, tearing Hartnell's clothing and damaging the tissues of his right forearm.

Hartnell was wrapped in a cotton shroud. He was wearing three shirts and no pants. On his head was a woolen cap, and his head rested on a small pillow. Underneath his body was a folded blanket. Like Torrington, his limbs had been bound to his body with cotton strips.

After the ice had been melted from around his body, it was removed from the coffin and taken to a special autopsy/x-ray tent erected adjacent to the grave. Hartnell measured 180 cm (corresponding to known family records) and it is estimated that his body weight was less than 40 kg. He had moderately long dark brown hair, and a red goatee-type beard. The still-clothed body was examined and x-rayed. The x-rays confirmed what we saw after removal of the clothing: Hartnell had al-

ready been autopsied by one of the surgeons on his ship (Notman *et al.* 1987). His anterior thorax and abdomen were marked by an inverted Y-incision which had been sutured shut. Our own autopsy was conducted over the next few hours, after which the body was prepared for reburial. Within 24 hours of exposure, Hartnell had been reinterred and his grave completely reconstructed.

Braine's coffin was uncovered at 2 m below the surface. There had been no previous disturbance of his grave. After removal of the ice around his body we found Braine also buried wrapped in a cotton shroud. He had on three shirts, no pants and a pair of folded stockings were tucked under his feet. His face was covered by a red kerchief. Braine's body was a greenish color, and it was obvious that it was already decomposing when he was buried. We speculate that he may have died away from the ships on a survey party, and it took a number of days for the men to return with his body.

Braine measured slightly more than 180 cm and he, like the other two, weighed less than 40 kg. Balding, his hair was dark brown/black and he had a moderately full black beard. Following the procedure outlined for Hartnell, Braine's body was first x-rayed, then autopsied. He was reinterred and his grave reconstructed within 24 hours of his first exposure.

## RESULTS AND DISCUSSION

### Autopsy Results

The most outstanding feature about these three individuals was their degree of preservation. Though histologic preservation was often lost, the gross appearance of most tissues and organs was remarkable. Autopsy procedures involved normal dissection methods.

Torrington's lungs were anthracotic and a fibrocalcific granuloma, possibly caused by tuberculosis, was identified (Amy *et al.* 1986). Pleural adhesions and intra-alveolar exudate suggest pneumonia. No other abnormalities were observed, other than the presence of dental caries.

Both Hartnell and Braine possessed caseating non-calcified granulomas of the lungs, with the granulomas containing acid-fast mycobacteria, probably *Mycobacterium tuberculosis* (Notman *et al.* 1987). The x-rays revealed that Braine had slight angular kyphosis of the spine due to the anterior collapse and wedging of T11, and probably a result of Pott's disease (Notman *et al.* 1987). Both men also had dental caries.

No evidence for trauma or dietary deficiencies, such as scurvy, were seen in the three sailors (Amy *et al.* 1986; Notman *et al.* 1987). Tissue and organ samples were also collected for bacteriological assessment and lead analysis.

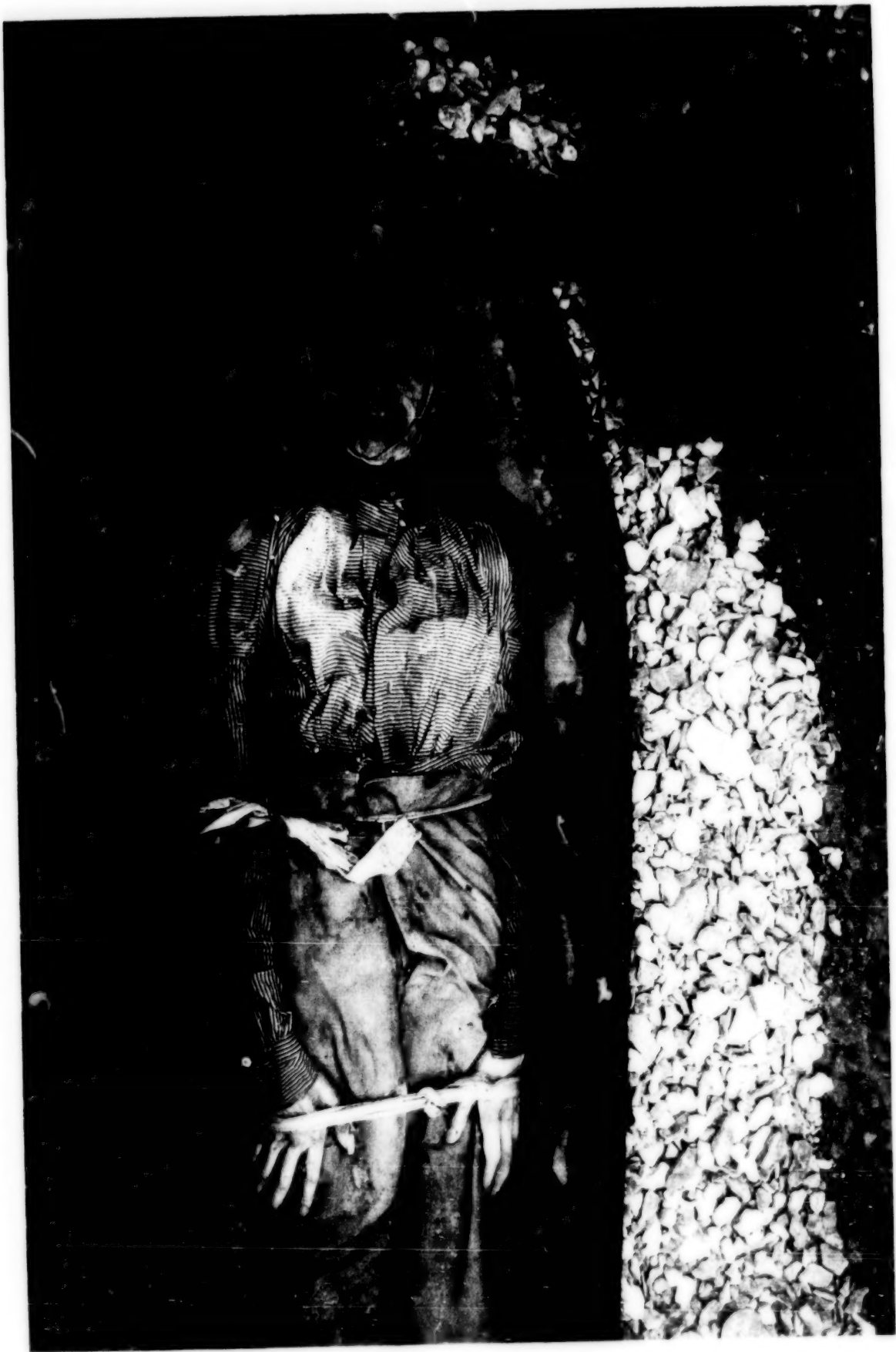


Figure 3a. The exposed body of John Torrington.

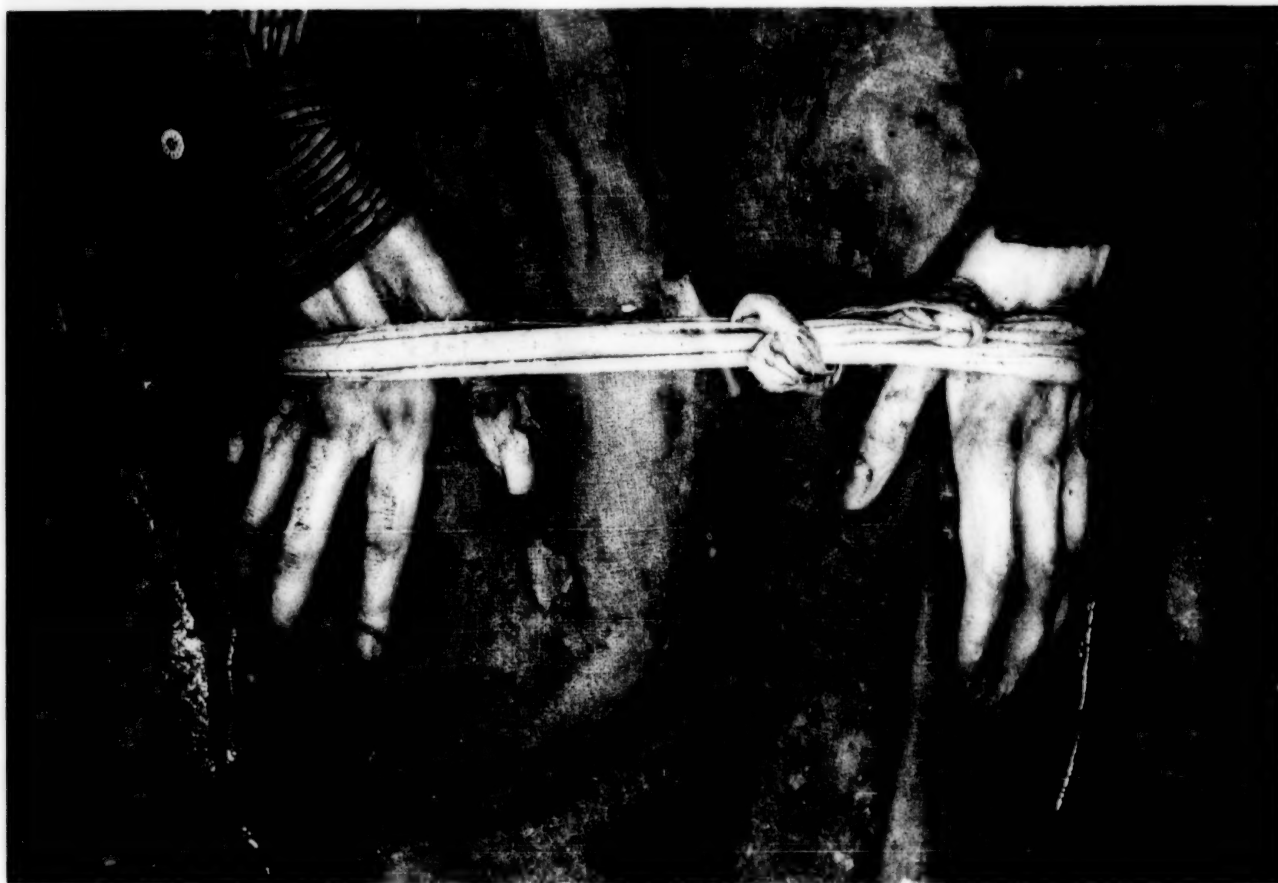


Figure 3b. Detail of John Torrington's hands.

### Lead Analysis

The lead and other trace element analyses are not yet completed, though some results have been published (Kowal *et al.* 1989, 1990).

Analyses of bone samples from Beechey Island by graphite furnace atomic absorption spectrometry average (in dry weight)  $128.3 \mu\text{g/g} \pm 45$  (range 69–183); bone samples from King William Island average  $138.1 \mu\text{g/g} \pm 35$  (range 87–223). Similar analyses of Torrington's hair yielded  $565 \mu\text{g/g} \pm 117$  (range 330–707), Hartnell's  $326 \mu\text{g/g} \pm 110$  (range 222 – 510), and Braine's  $225 \mu\text{g/g} \pm 90$  (range 158–317) (Kowal *et al.* 1989:125). All of the materials from King William Island and Beechey Island (representing from ten to eighteen individuals) had these elevated lead values.

The bone values exceed those reported by Barry (1975) and Green *et al.* (1978) for modern industrially exposed individuals, and compare with other archaeologically derived materials interpreted as indicating lead poisoning (Corruccinni *et al.* 1987). The significance of these findings relates to the degree to which the lead exposures produced symptoms that would endanger the lives of the sailors. The encephalopathy,

behavioral changes, extensor muscle paralysis, weakness, fatigue, and abdominal colic associated with adult lead poisoning could have had a devastating effect on the crews already exposed to considerable environmental, dietary, and psychological stresses. The circumstances surrounding the desertion of the ships (including the prior loss of 24 crew members), the decision to head south instead of north (where they may have expected rescue by whalers), and the circumstances surrounding the time on and around King William Island, all point to highly questionable, and arguably irrational, decisions being made by the officers (see Beattie and Geiger 1988). The lead findings provide new evidence for an explanation of these behaviors that have baffled many searchers and historians for well over one hundred years.

A report on soft tissue and organ lead content is presently under review. These data correlate well with the bone and hair lead levels. The soft tissue results, along with the published hair data, indicate that the men were being exposed to lead from some source on the expedition. A review of the equipment and supplies for the two ships shows that the most likely sources of exposure were the fluid storage and food preparation material, and the 8000+ cans of preserved food prepared



Figure 3c. Detail of John Torrington's feet.



Figure 4. John Torrington, showing the slight dissection of his eyelids and mouth. Note the dental caries on the maxillary left and lateral incisor.

for the expedition (Beattie 1985). From sheer quantity, the canned foods appeared to be the most likely and pervasive source for all of the men. Lead isotope analyses by thermal ionization mass measurement of lead from the tissues of the sailors and solder from Franklin expedition cans showed a very high degree of correlation (Kowal et al. 1990). This is convincing evidence that the only significant source of lead on the expedition was the canned foods.

#### **A Discussion on Food Canning Technology and the Canned Food Supplied to Franklin's Expedition**

The technology relating to the preservation of food in sealed metal canisters was patented in England in 1810 (International Tin Research and Development Council 1939). This was an expensive means of packing food, but the gains in quality, reliability, and relative ease of transport found immediate application in exploration and the military. From 1814 to the 1840's the use of canned foods in Arctic exploration expanded: the reli-



Figure 5. John Hartnell's coffin, showing the damage done by the explorers in 1852.

ability of the food, and its palatability and sustained quality over the passage of time, allowed for the planning of larger, longer and more ambitious expeditions. The supplier who won the contract to provision the Franklin expedition with canned foods was Stephan Goldner (Cyriax 1939; International Tin Research and Development Council 1939). This was his first contract with the Royal Navy. There has always been some question as to the quality of the food supplied by Goldner to Franklin's ships, and Goldner was later implicated in massive food quality and spoilage problems of later Royal Navy projects.

During the time of Franklin's expedition cans were made by hand (Busch 1981; International Tin Research and Development Council 1939). Usually, the body of the can was made by bending a rectangular sheet of tinned wrought iron around circular mold, forming a lap seam at the overlapping edges. This seam was soldered internally and externally. Next, the top lid of the can, with flanged edges, was slipped over one end of the body and soldered internally to the body. This lid pos-

sessed a large hole (called a filler hole), usually in the center, that would allow for the later packing of the can with food. The bottom of the can was then slipped on and was soldered internally by passing the soldering iron through the filler hole on the top of the can. Therefore, when the can was sent off for packing with food it was virtually complete. The food packing procedure consisted of hand-packing the food through the filler hole; the packed cans were then cooked by nearly completely immersing them in hot water or a hot salt solution. Once the food was cooked, a metal disc was placed over the filler hole and soldered to the lid. Often, a small hole was present in the lid, and this steam to escape during the final stage of the cooking process. Before the can cooled this hole was also sealed with solder. When the sealed cans cooled a partial vacuum was produced.

In hindsight, it is clear to us today that the general quality and safety of these types of cans was highly suspect, though there was some realization of this during the latter part of the 19th century (Anon. 1883:271):

The danger of contamination from the lead contained in the solder depends upon the way in which the can is made. . . . In a hand-made can by a careless workman, a square inch or more of solder surface may be present on the inside of the can. Drops of solder may also fall into the can in the process of sealing, and most of our readers must have seen such fragments of solder. If they have not, their cooks have.

Our observations and analyses of emptied cans from Franklin's expedition collected at Beechey Island indicate that up to 30% of the inside surfaces were covered by tin/lead solder. The lead content of solder from this time period was 40% to 50%. The main types of food supplied to the expedition were meats, gravies, soups, broths, and vegetables. All of these foods were acidic in nature, increasing greatly the degree of the mobilization of the lead from the solder into the food. There is little doubt that the food in the cans was at great risk of contamination from the lead in the solder.

Canned foods were at first considered a luxury, but in the latter half of the 19th century they became "...almost a necessity" (Anon. 1883:270). The medical literature from this period does contain a number of accounts of lead poisoning attributed to the consumption of food preserved in cans (Wightwick 1888; Rosenberger 1884; Magruder 1883, 1884). Certainly by 1883, and probably much earlier, the most potent danger of canned foods was seen by some to be "metallic poisoning" due to lead (Anon. 1883). By 1884, in both Europe and North America, investigations were under way relating to the determination of the danger to the public health from the use of canned food (Magruder, 1884). At least one doc-

tor recommended "...the desirability of the medical profession offering an earnest veto against the preservation of articles of diet in tins...", and even in 1881 *The Lancet* asked "Why not substitute bottles for tins?" (Wightwick 1888:1121). This was a controversial topic at the time that provided a serious threat to the trade, which had large capital investments in the technology and employed many people (Johnson 1884-5).

As a guide to home canners, the *Medical News* of 1883 (Anon. p. 271) warned: "In cases of obscure nervous affections look out for lead-poisoning, and bear in mind the use of canned food as a source of such poisoning". This comment is testimony to the growing suspicion (if not alarm) during the late 19th Century (supported by clinical observation) that lead from preserved canned foods may have been having some profound and not fully-understood effect on people. As for the effects of canned foods on Arctic explorers, at least one other disaster has been linked to lead poisoning, the unsuccessful expedition of the Arctic steamer *Jeanette* to the north pole in 1879. Magruder (1883:263) quotes from, and comments on, the Report of the Court of Inquiry on the expedition:

On page 30, Liet. Danehower, in answer to this question by the court, "did the character of the provisions supplied to the *Jeanette* cause sickness at any time?" said, "In May 1881, a number of the people became affected with stomach disorders, which were attributed to tin-poisoning. It had been observed that the inside of the tomato cans had turned dark, as though acted upon by the acid. . . ."

On page 36, in answer to a question by the Judge advocate as to the physical condition of the men when landed on the ice, June 1, 1881, the same witness said, "...Lieut. Chipp was disabled and prostrated by what was supposed to be tin-poisoning . . . . A number of men . . . were also affected by the tin-poisoning, and were prostrated a few days later."

I have no doubt that the so-called "tin-poisoning" was really lead-poisoning, resulting from the use of cans coated with the alloy of tin and lead.

Our own discoveries and suspicions regarding the negative health effects of lead ingestion during prolonged exploration were obviously not the first; by the end of the Nineteenth Century the practice of sealing cans by soldering the inside surfaces was discontinued (Beattie and Geiger 1988).

#### Other Research in Progress

During the autopsies of Hartnell and Braine, tissue and organ samples were collected under sterile condi-

tions for bacteriological analysis. Later laboratory culturing of samples from the abdominal contents yielded six strains representing three species of *Clostridium*. At least two strains demonstrated partial resistance to certain antibiotics (Kowalewska-Grochowska *et al.* 1988). The significance of these discoveries is presently under investigation.

The preservation at Beechey Island has also provided a unique situation for the study of the clothing and textiles not represented in museum collections today. In 1984 small samples of all perishable materials (clothing, textiles, wood) were collected for later analysis. In 1986 an Arctic clothing expert was present on the site to analyze the clothing and textiles, to make patterns of the clothing, and to collect samples for later analysis. Although this work is still in progress, some of the results have been published (Kerr and Schweger 1989; Schweger and Kerr 1987).

Reports on the metallurgical analysis of cans form the Franklin expeditions collected from the Beechey Island site are in preparation.

### SUMMARY

Since 1981 multidisciplinary research had been conducted into the third Franklin expedition mass disaster. The primary conclusions of this research has suggested that the toxic metal lead, originating from contaminated canned foods, poisoned the crews. As canned foods were one of the food sources relied on by Franklin and his men, all of the sailors would have consumed some amount during the course of the expedition. Therefore, the serious, often lethal effects of lead poisoning are now considered to be a key element in the cause of the disaster.

The identification of lead contaminated food containers from the time period of the expedition raises one thematic question: what possible effects could canned foods have had on other expeditions, military exploits, or on the general populace? I believe we do not yet appreciate what role this technology played in the general health of 19th century consumers.

### ACKNOWLEDGEMENTS

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## RECONSTRUCTIVE ANALYSIS OF THE SPACE SHUTTLE CHALLENGER

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This paper describes the reconstructive analysis of the Space Shuttle Challenger. All remember where they were on that day when the Challenger broke up in flight off the coast of Florida. That date, of course, was January 28, 1986.

I was the director of accident investigation for the National Transportation Safety Board (NTSB) in Washington, D. C., at that time. Consequently, I was responsible for all the major air carrier disasters and other accidents that related to the surface transportation modes. I had 10 years previous experience with the Naval Safety Center. This helped me immeasurably in reconstructing, analyzing and causing to be analyzed all of the components from the Space Shuttle Challenger.

The components that were analyzed were from the break up of the Challenger. This was viewed many, many times and it truly was an in-flight break up. It was not an explosion and fire, but a break up which happened at about 13,000 m at a Mach number of about 1.9. It occurred during the portion of the flight at which the shuttle was going through its maximum aerodynamic pressure maneuver. This was the maneuver where the space shuttle does its roll and positions itself for the down-range orbit that it is shooting for. Under those circumstances it was pulling about four times gravity (4 G's). This was not really an extreme load. One can pull that comfortably, and more, if you are in good condition with a gravity suit during air to air combat. The shuttle, however, was a bigger and a more massive piece of equipment, weighing almost 2 million Kg and under 3.2 million Kg of thrust. So it had a good thrust to weight ratio which was required to get it to go Mach 25.

Although the break up occurred at about 13,000 m, the remainder of the debris traveled to approximately an apogee of 20,000 m. At this point the two solid rocket boosters had not finished their full firing thrust sequence of two minutes. They were still about 20 minutes away from exhausting their solid propellant and were detonated by the range safety device officials at the Kennedy Space Center. That was the only thing that was detonated. These officials also have the ability to use the detonating cord and blow the external tank apart. The reason for the detonation was to keep the debris from returning back over the Cape or other populated areas.

They did not fire the external tank because the tank had already torn itself apart.

I received a call on January 29th from the director of Kennedy Space Center, who asked for NTSB assistance. There was no NASA plan for an in-flight failure. They did have an industrial accident plan. They also had a plan for something that would occur once the solid rocket boosters burn time ceased, and they would fail to detach from the external tank while it headed on up to orbit. Then the astronauts could actually fly the shuttle and get away from the external tank if it was necessary, and make a glider landing at one of the recovery facilities. There were no parachutes and no ejection seats. They did away with the ejection seats after about the fourth successful flight. This was because the three man crew up front had ejection seats but the passengers did not. They also did not wear any sort of fully pressurized space suits during the launch and insertion as they do now. They were in very comfortable flight suits (shirt-sleeved type). The astronauts that were in the lower deck during the ascent, were in recliner type devices that placed the body horizontal to the main G pulling that was occurring. They were flat on their backs and in that position the G pull would not bother them.

NASA requested NTSB assistance on scene. Obviously no one from NTSB, the air carriers, the U.S. Navy, Army, or Air Force, ever considered an accident investigation of the space shuttle. I inquired as to what had been done and they said they had recovered, from the surface of the ocean, five semi-trailers full of debris. This material was in a safe facility with a tarps over it. The debris consisted of a little bit of everything; parts of the orbiter, parts of the external tank, parts of the solid rocket boosters, and fragments and pieces of material that may have come out of the command module. The first concern I had was whether they had given the debris a fresh water washdown. Ocean water and the gulf stream area are highly polluted. From an accident investigator's sense, it is polluted because there is a lot of oxygen in that water and a lot of salt. Aluminum and all components of aircraft structures with possibly the exception of titanium and stainless steel, would corrode as soon as it was exposed to the air. They had not given the debris a freshwater wash down. I inquired if they were planning

to bring up the majority of the wreckage and the answer was yes. They indicated they had ships on the scene and had recovery ships enroute. I talked to the NTSB director of technology and NTSB chairman and we made the decision to provide them assistance.

We flew down the next morning and met with all of the space center's directors, the deputies and engineers, and we discussed what the NTSB could do. We offered to provide them with our background and experience with super sonic break ups in-flight, in-flight collisions, and in-flight fires and explosions. With an in-flight break up, as with the shuttle, the parts all fly in their own separate directions. The dynamics cause the parts (now debris) to tumble and strike each other. Then there was water impact damage from terminal descent into the water. There also would be damage done under the water with the debris sitting on the bottom, slipping and moving back and forth due to the current in the gulf stream. Sand further contributes to the damage as it acts as an abrasive sandpaper against the surfaces of the fractures. Lastly, there would be damage during the recovery.

The underwater salvage dealt with debris from the Challenger spread out over a 24 Km range and at least 4 Km to either side when it came down. We got the equipment in place to begin the recovery. We used equipment that could lift large pieces of debris as we were dealing with some 2 million Kg including the two big boosters. Despite that we could not recover everything. We did not recover the left wing. We did get it to the surface and took a video shot of it, but there was no way to lift it out of the water. We recovered about 70% and would have had 80% if we could have recovered the left wing.

I had a number of laboratories available to me for analysis of debris, including the FBI Laboratory, if we had asked them. There were three laboratories available, JFK, Marshall and Johnson, each with capabilities for full fracture, metallurgical and chemical analysis.

I stayed at the Kennedy Space Center for the next 4.5 months on loan to NASA as the director for reconstruction and analysis using conventional aircraft mock up techniques. We did have some organizational difficulties as NTSB organizes parties differently than NASA. We also experienced some difficulty in dealing with brand new people in the aviation industry. We were used to vendors such as McDonnell Douglas, Boeing, Pratt Whitney and General Electric. We were now dealing with vendors such as Rockwell International, Morton Thiokol, Martin Marietta, and Rockeddyne, plus the Navy, the Coast Guard and contractors involved with the salvage. We had six ships and three remote operating vehicles operating around the clock.

We did get good photography of everything. We also did a lot of underwater photography, in addition to photography of items recovered on the ship itself.

At the time of the launch there was a cargo load of 17,800 Kg in it, along with military cargo. This played no role in the break up of the Challenger but it did provide some valuable evidence as far as vectors and forces, and the amount of weight that it ejected out of the cargo bay during the break up.

NASA had in-flight telemetry, in-flight tracking, and in-flight videos. They did not have any flight data recording devices. They did have radar, which is metric radar, but it was only able to track basically about five or six objects. That was all they needed really for normal flights. They had the external tank which came off later and the two solid boosters which would come off and they wanted to track those for an accurate splash down. Obviously, they would follow the orbiter itself until it disappeared. When the shuttle broke apart we had probably 500 to 1,000 pieces of debris flying around and the radar could not handle that. The video only really showed that there was a huge, huge cloud of vapor with 2 million liters of liquid hydrogen and oxygen obscuring everything until small pieces of debris came out of that cloud. Then the two solid rocket boosters crossed and went all over the place and created what looked like a hyperbolic burn. It was not a controlled burn of that amount of fuel; just some splotchy burning that occurred.

There was a photograph that provided a valuable clue. We were able to see a big puff of black smoke right at this O-ring on the right hand booster. That smoke disappeared after this initial puff. This puff was on the initial firing of the right hand solid. The inner tank was not machined aluminum, but was acid etched aluminum to get it perfectly aligned and stress free. There was a bean bag shaped tank which held all the oxygen and then a huge tank that held all the hydrogen at a ratio of 1:5. There was the effect of a corrugated cardboard, which was covered by spray on foam insulation (SOFI). That was because you have a temperature of  $-279^{\circ}\text{C}$  in this tank, like a big thermos bottle. This material flakes off as the shuttle accelerates through high Mach numbers. The tanks always tumble into the ocean when they are released somewhere below 120,000 m. It has a tumble valve in it and it tumbles and breaks it up so that it comes floating down. After the Challenger broke up pieces of this tank took almost 15 minutes to fall to the surface of the water because it was affected by flat plate drag. It just floated down like leaves.

The failure area manifested itself when the shuttle approached its roll maneuver. Both boosters were firing a nice plume and the three big hydrogen-oxygen engines were firing at full power. Then the break up occurred and once could see what appeared to be a fire ball situation. It was very deceiving in that effect because we had another booster over on the other side that was shooting through. There was some ignition. However,

when we laid the wreckage all out, everyone expected it to be very badly burned and scarred. It was not. There was only minor in-flight fire damage. Because of the oxygen rich fuel mixture the titanium nozzles burned off at about 2200°C.

One item that helped in the reconstruction were the tiles. They are reinforced carbon on carbon, with various thicknesses ranging from as much as eight cm down to about two cm. There are about 35,000 tiles on the orbiter and they are glued on. Each tile has its own number and each tile is slightly different in dimensional characteristics than another, so no two tiles were alike. The tile drawings made it extremely helpful when we reconstructed something that was broken up. In the reconstruction efforts, as the pieces came up from underwater, we would identify them by their tile numbers, go to the tile drawing and we knew exactly where to lay these tiles out in the hanger.

We did a crack plane analysis, which is similar to what we do in aircraft accident investigation. In a ductal type failure or even in a brittle type failure you can tell which direction the metal was tearing and separating. There were lines of flow that provided this information. I saw almost right away that everything looked like the nose section had come down and that the orbiter's capsule itself had torn out of this. This happened on impact with the water. The forces were too great and the density of the air up there was just not that much. Once they got to 18,000 m it turned around and came down intact because that was where we found it, all in one spot.

All these fractures surfaces had to be completely treated against corrosion and we used a type of petroleum protection. We used soft bristle paint brushes to apply the petroleum material and just keep brushing the fracture surfaces because we did not know what fracture surface might have fatigue striations or which might have some pre-existing failure. We went on the premise that we had no idea what happened and in fact during this time we did not have any idea for sure what had happened. The left wing, which we found after three months on the bottom, came up intact. Also, the right hand tail sections showed some unusual pitting damage. Also on the right hand side, on the flapperon areas, exhibited molten titanium indicating spontaneous ignition. Therefore, we thought something was very curious, was really different between this right wing and the left wing.

Many spectrographic samples were taken. There were pock marks on the shuttle and in these pock marks was aluminum perchlorate, aluminum powder and iron oxide. This made up the booster's solid rocket fuel. We also found ferrous oxide, a lot of steel, or ferrous material. We wanted to know the direction in which the majority of these pock marks were receiving their hits.

To determine this we had a measuring method with a little caliper and a divider. We had to go ahead and place small wands into a sampling of these pock mark craters. Admittedly, rather empirical, but it gave us an idea of the direction that the impingement was occurring on the speed break itself. The speed break was receiving something in excess of 2200°C and the tiles could not withstand that.

When the external tank was punctured, liquid hydrogen was being lost at an enormous rate therefore, you were getting more oxygen rich fuel to the engines. They burned right out to their mixer tubes and that was one of the things NASA felt may have caused the failure. If such a failure had occurred in the engine bay then the orbiter would burn up. Well, we found out that they burnt out so quickly that they did not do much damage to the internal engine bay at all. It did soot up a bit and threw a bit of molten debris around but did no real damage since the orbiter had almost no fuel on board. The exception was the fuel that the orbiter would use for maneuvering at altitude in space. None of this fuel caught fire either, although NASA was convinced that this is what caused the explosion. It did not. All the fuels that were used to run the orbiter maneuvering engines were Kelvar wrapped. Two of them caught fire and they did burn when they fell from altitude. But it was very clear that they burned as they were falling through free air and they did not burn in the cargo bay and in themselves.

It was initially assumed that the nose wheel itself and the orbiter, just broke away completely, but it did make contact with the tank and that caused the beginnings of the break up. She started the flex in a positive direction and then as she pitched up and off and rolled and she got into a negative downward mode and pulled about 22 negative G's.

The tendency for accident investigators, is to take burned pieces and put them in a big pile or lay them out together, and take unburned pieces and put them in another pile. We put the pieces together like a jigsaw puzzle. We forgot about trying to put clean pieces together and the burned pieces together. We just placed the pieces to fit. It told us that the tank was broken up prior to any ignition or being whetted with liquid hydrogen and liquid oxygen or monomethyldihydrosene before it caught fire. It told us we did not have any kind of in-flight fire that contributed to the break up. The O-ring assembly failed and began to leak and then we had an impingement directly on the hydrogen tank itself. That was all it was. Just a direct, blow torch impingement of solid rocket booster fuel and it was doing two things. One, as it was impinging on it, it was attempting to burn through the aluminum, through the SOFI. Two, it was spewing ferrous material out. Obviously the booster case itself was melting at about 3300 to 4400°C. The problem

was that it picked that clock code position to fail. Any other clock code and most likely the orbiter would have continued to fly on out of this, in probably a yaw maneuver, but it would have continued on. But, then the aerodynamic force and flow came back across and impinged directly. It took an attaching point to weaken, that is, to become plastic under high temperature, and then the attaching point pulled out. These have explosive charges, but none of them cooked off. They were protected and they did not fire from the heat. They burned away completely all of the SOFI material.

The attaching point was large enough so that it prevented the heat flow from burning the SOFI off, but it burned deeply into the metal. This was the positive proof that we had a failure. The thrustum had a big heavy gouge mark. The booster itself hinged outward away from the tank and dug its nose section, conical nose section, and continued to fly right into the tank itself, through the tank, and rupture the liquid oxygen tank. We got flash burning that occurred by having the material saturated with hydrogen and oxygen and it happened to be homogeneous enough to ignite. We did not have this evidence until we brought the solid rocket boosters up.

The right hand wing took a blow when 12,700 Kg of cargo suddenly slammed the right wing. The cargo suddenly assumed the new inertia and the spreader bar took the load and bent itself and was permanently deformed. This was consistent with the right hand problem.

We had underwater photography continuously to make decisions if materials was worthy of bringing up. If we did not know what it was, we would bring it up. We used some innovative measures to raise some huge chunks. If it was a lightweight case and if it gave a serial number, we knew it was part of the right hand booster that we needed.

When we recovered the crew module itself was that, all of the personal environmental breathing systems had been activated. In other words, they realized after the nose section broke off that they were flying free and tumbling, so they did activate the systems, but to little avail. All of the bodies were almost identical as far as the injuries that they sustained, the hyper extensions of the necks and heads. All of the seat belts and lap restraints failed in the same direction as if the crew module had

broken free of the orbiter and had struck the surface of the water at about a 60 degree left wing down and 30 degree nose down. When it hit, at about terminal tunnel velocity which was about 257 KmPH or so, it crushed just like a styrofoam cup. Then it slowly sank directly in only 24 m of water. It became covered with silt and we almost did not find it. We found it when we were looking at a unique piece of debris that proved to be cargo. As we pulled up that piece of cargo we saw a big section of the crew module itself, that just uncovered itself in the sand. We brought it up and we mocked it up completely, and mocked up all the cockpit area also. We looked at all of the personal lockers and all of the areas where items are stored. Interesting things occurred, toothpaste for instance, had all burst apart and then had kind of mooshed itself together. The astronauts personal 35 mm cameras had aluminum screw on lens caps that had a direction of failure in a compression mold, in other words they were concaved.

It was thought this was a result of instant depressurization, explosive decompression. When we looked at it in the metallurgical laboratory we saw two kinds of failure. We found a convex failure, but not very much, and then water pressure, once underwater gave it the concave effect so it worked it in both directions. Everything that failed as far as where they store things was all in a certain direction which told exactly which way it hit. We were able to calculate the velocity.

Interestingly, equilibrium had been reached within its firing chamber. If the shuttle had just gone straight into space with no G maneuver or roll maneuver it would not have leaked again. However, it melted the outer O-ring and the secondary O-ring but it clogged itself up with carbon deposits. It was not going to take any long column bending stress or G maneuvers. Then it just cracked all that crust, and there was not enough crust build up to reclose the leak. This allowed the escaping gases to find the hole and melt through. To position it for its ultimate maneuver to go down range, the shuttle must perform a roll maneuver.

In summary, computer imagery and modeling together with the results of the reconstruction showed the destruction of the Space Shuttle Challenger to be an in-flight break up.

# MEDICAL CONSEQUENCES OF BUILDING COLLAPSE: COORDINATING MEDICAL AND RESCUE RESPONSE

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Sudden impact disasters such as earthquakes present a serious challenge to both developed and less developed countries of the world. During the past twenty years, earthquakes have caused more than a million deaths worldwide. A review of the disaster medical literature reveals a general consensus among researchers and disaster planners alike, on the inadequacy of preparedness programs in communities at risk of disasters such as earthquakes (Guha-Sapir and Lechat 1986a). This inadequacy, stemming from a lack of appropriate information and research, may result in ineffective and wasteful relief action and marginally-developed preparedness programs (Noji 1987). For this reason, we must rely on lessons learned from past earthquakes, particularly regarding the exact nature of immediate medical needs (de Bruycker *et al.* 1985; de Ville de Goyet and Jeannée 1976). Better epidemiologic knowledge of the causes of death and types of injuries and illnesses caused by earthquakes is clearly essential to determine appropriate relief supplies, equipment and personnel needed to effectively respond to such situations (Armenian 1989; Guha-Sapir and Lechat 1986b; Binder and Sanderson 1987).

Successful search and rescue endeavors consist of rapid location, access, extrication, stabilization and transportation of victims (Table 1). Since victims of building collapse may be trapped for hours, if not days, it is important that SAR personnel also be trained to resuscitate and stabilize such patients while they are being extricated. In the case of Mexico City, more than 400 major buildings were seriously damaged, and there were more than 40 major collapses of reinforced-concrete buildings (Sanchez-Carrillo 1989). It is estimated that more than 10,000 people were trapped in collapsed buildings as a result of the earthquake (Zeballos 1985) (Figures 1 and 2).

**Table 1. COMPONENTS OF SUCCESSFUL  
SEARCH AND RESCUE**

- |                  |                  |
|------------------|------------------|
| • Rapid location | • Stabilization  |
| • Access         | • Transportation |
| • Extrication    |                  |

When comparing the number of injuries to available trained medical personnel, it becomes very self-evident that scarce resources must be used where they will do the most good. In other words, SAR personnel must be able to rapidly determine approximate number of victims, probable locations of survivors, and potential for survival.

The aim of this paper is to address this problem, that is, given that earthquakes and building collapses will occur, how can the number of deaths and injuries be minimized. Specifically, what needs to be done to improve medical planning, preparedness and response to



Figure 1. Collapse of Juarez Hospital in Mexico City, 1985. Photograph reproduced here with the permission of the Pan American Health Organization.

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earthquakes. It is clear that the increasing frequency of disasters in large urban areas, coupled with the collapse of reinforced concrete buildings, calls for a more professional approach, especially specialized medical and rescue skills. The paper will outline a number of important endeavors that are deemed necessary to achieve this important goal.

## EARTHQUAKE PREPAREDNESS AND RESPONSE

### Seismic Vulnerability

There are large areas in the United States that have high seismic risk. These include such areas as the Puget Sound, Salt Lake City in Utah, the New Madrid region and Charleston, South Carolina (Figure 3). There are many buildings in these potentially seismic areas which are not built to withstand significant ground shaking and which would be subject to catastrophic collapse in a major earthquake. Unfortunately, while such disasters



Figure 2. Successful extrication of live infant from Juarez Hospital in Mexico City, 1985. Photograph reproduced here with the permission of the Pan American Health Organization.

U. S. Seismicity: 1960-1988

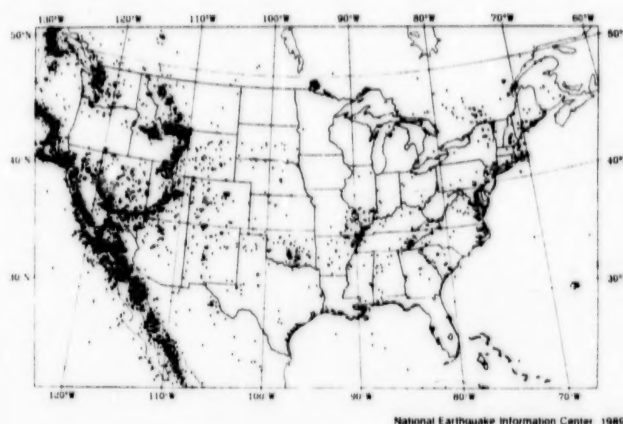


Figure 3. Seismic activity in building collapse.

are feared by the earthquake engineering community, much of the population of dangerously seismic areas in this country have not exhibited consistent concern about the risk.

### Local Response

Search and rescue personnel operate under a very constrained time element. Survivable time for victims of building collapse is measured in minutes and hours, but response time for outside medical aid may be measured in hours, if not days (de Bruycker *et al.* 1983). With the exception of personnel from countries in close geographical proximity, external medical assistance will arrive after local health services in the affected country have already provided emergency medical assistance (de Ville de Goyet and Jeannée 1976). Foreign health experts with specialized expertise in areas such as on-site resuscitation and medical first aid usually arrive too late. "First responders" after an earthquake will be relatively uninjured survivors- volunteers, friends, neighbors and relatives of the victims (de Bruycker *et al.* 1985).

Unfortunately, in many highly seismic parts of the world, the public has come to be virtually completely dependent on professional health personnel such as physicians, nurses and paramedics to provide emergency medical care. For that, and a variety of other reasons, the general knowledge of life-saving first aid procedures and personal survival techniques is generally low.

A general apathy among the lay population in countries at high risk for earthquakes, as well as among health care organizations and governments has left the survivors of disasters such as earthquakes vulnerable if an event compromises the formal medical system. This was dramatically illustrated in Armenia where large numbers of health care personnel were killed or injured and all hospitals were destroyed or rendered non-functional

in the earthquake devastated parts of the country (Noji 1989a).

Therefore, when a major earthquake strikes, untrained local people supplemented by surviving fire, rescue and emergency medical personnel, and still functioning hospitals will do their best to cope with the initial onslaught of large numbers of seriously injured patients while awaiting outside aid. Countries vulnerable to earthquakes should establish continuous programs for public motivation, and education regarding what to do when an earthquake occurs, first aid, and organized volunteer work.

### Earthquake Morbidity and Mortality

During the past twenty years, earthquakes have caused over one million deaths. Approximately 1,600 deaths attributed to earthquakes have been recorded in

the U.S. since colonial times of which more than 1,000 have occurred in California. These include 700 in the 1906 San Francisco earthquake, 64 in the San Fernando quake of 1971 and 67 most recently in the Loma Prieta quake of 1989.

The factors determining the number of people killed after a building collapses are (1) level of occupancy, (2) circumstances of entrapment, (3) injury severity and the length of time victims are able to survive without medical attention, and (4) how quickly victims are rescued and receive medical attention (Coburn *et al.* 1987). One of the biggest handicaps in trying to develop realistic medical plans, and determine medication, manpower and supply needs is the total lack of any real specific injury data on earthquakes. Sketchy data on relative numbers of injuries exist, but no information on how a victim was injured or the actual numbers of victims in

## Epidemic feared

Gorbachev asks removal and quick burial of quake dead

MOSCOW (UPI)—President Mikhail Gorbachev, standing on the rubble of the earthquake-mashed city of Spitak in Soviet Armenia, told rescue workers Sunday they must save as many dead before epidemics strike and bodies are buried.

In 20 minutes of remarks shown to the public on the television evening news, Gorbachev also promised Armenia an investigation into why some buildings collapsed in Wednesday's quake while other structures remained standing.

He said that when the rescue and cleanup are completed, a government commission will look into the question.

Why did buildings from three centuries collapse while those built last week or five decades later remain? Premier Levon Ter-Petrossian, who did not speak, he asked in an angry tone.

Soviet buildings are notoriously poorly constructed, but the public admission of that by a top Soviet official is rare.

In an emotional exchange, a man in the crowd that surrounded Gorbachev on a Spitak street, he pleaded to know why scientists did not predict the earthquake, which has killed at least 40,000 people, according to official estimates.

"We are studying such demands," the Soviet leader told the man. But he added, "So far, nowhere in the world do they have methods to predict earthquakes." He said Heoan Mikaelov, Yevgeny I. Chuprin had advised him that the weather conditions in the disaster area could create a threat of an epidemic seven days after the earthquake. Bodies buried under the rubble must be removed to avoid an outbreak, he said.

Gorbachev told the rescuers that doctors and health officials have devised emergency measures to ease an epidemic strike. He did not elaborate.

The Kremlin chief did not specify what kind of epidemic might break out. But destruction of urban water supplies and pollution from decaying rubbish can spread deadly diseases such as typhoid and dysentery.

Later, Gorbachev praised the outpouring of assistance from throughout the Soviet Union for earthquake victims.

"We are proud of all our people," he said. "What immense moral strength they have!"

The priority in the rescue work is said to be to save people still trapped under the piles of crumbled debris.



Soviet President Mikhail Gorbachev, center, day's earthquake during a tour Sunday of the foreground, talks with survivors of Wednesday's devastated Spitak in Soviet Armenia.

"First and foremost, we must help to clear these piles of rubble where there are still many people alive. Because people are being

trapped there every day. I have seen some of them in the first case, but first thing being done is to save those who are still alive."

"Those who have remained must also be given as much help as possible. They need food, clothing, shelter, and other things."

Figure 4. Despite rumors of epidemics, outbreaks of infectious disease such as cholera or typhoid generally have not followed earthquakes.

any given earthquake (Armenian 1989; Smith 1989; Noji 1987)

Trauma caused by partial or complete collapse of man-made structures is the overwhelming cause of death and injury in most earthquakes. Indirect hazards include post-earthquake fires, hazardous chemical and radiation release, electrocution, injury during rescue or cleanup operations, acute myocardial infarction and exacerbation of other chronic diseases, anxiety and other mental health problems, respiratory disease from exposure to dust and asbestos fibers from rubble, and flooding from broken dams. Outbreaks of infectious disease such as cholera or typhoid generally have not followed earthquakes in other countries and are unlikely in the U. S. as well (Alexander 1982; de Ville de Goyet *et al.* 1976) (Figure 4).

An extensive earthquake planning scenario has been developed for a magnitude 8.3 earthquake along the San Andreas fault (NOAA 1972; NOAA 1973; Moorhead *et al.* 1984). Although the casualty estimates produced by these studies are plagued by high degrees of uncertainty, they suggest that up to 25,000 persons will be killed and possibly 100,000 seriously injured. As mentioned above, such estimates must be interpreted with caution since they are based on assumptions and past earthquake data of questionable validity. Major injuries will include skull fractures with intracranial hemorrhage (for example, subdural hematoma), cervical spine injuries with neurologic impairment, and damage to intrathoracic, intraabdominal and intrapelvic organs (for example, pneumothorax, liver lacerations and ruptured spleen) (Table 2). Most injuries will be of a combination nature (for example, pneumothorax in addition to an extremity fracture) (Figure 5). Results from more recent earthquakes in Coalinga (1983), Whittier (1987) and Loma Prieta (1989) suggest that in an earthquake of lesser magnitude (for example, 6.5 – 7.1), deaths will be relatively uncommon and the majority of injuries will be minor (for example, contusions, sprains, lacerations, extremity fractures, etc.) (Noji *et al.* 1990). There will also be an increased incidence of certain medical conditions brought on by earthquake-related stress such as myocar-



Figure 5. Most earthquake-related injuries will be of a combination nature. Here is a child with a fractured skull and arm, injured in the 1988 Armenia earthquake.

dial infarction and hypertensive crisis as well increased numbers of earthquake victims presenting with psychological problems such as severe anxiety and depression (Katsouyanni *et al.* 1986; Trichopoulos *et al.* 1983).

Hypothermia, secondary wound infections, gangrene requiring amputation, sepsis, adult respiratory distress syndrome (ARDS), multiple organ failure and crush syndrome have been identified as major medical complications in past earthquakes (Andrews and Souma 1989; Collins 1989). Crush syndrome results from prolonged pressure on limbs causing disintegration of muscle tissue (rhabdomyolysis) and release of myoglobin, potassium and phosphate into the circulation (Ron *et al.* 1984). Systemic effects include hypovolemic shock, hyperkalemia, renal failure and fatal cardiac arrhythmias (Atwater 1983; Kitka *et al.* 1987; Michaelson *et al.* 1984). Patients with crush syndrome may develop kidney failure requiring dialysis with an artificial kidney machine. In Armenia, thousands developed kidney failure which completely overwhelmed the region's capacity to deliver such high technology care for such large numbers of victims.

Heavy dust has also been reported immediately following earthquakes and among trapped victims, and may be a life-threatening hazard due to asphyxiation and upper airway obstruction (Hingston and Hingston 1983) (Figures 6 and 7). Asbestos and other particulate matter in the dust could pose both subacute and chronic respiratory hazards to entrapped victims as well as rescue and cleanup personnel, depending on the characteristics and toxicity of the dust.

#### Time Factor

It is clear from recent major earthquakes that emergency medical needs, ones that require the rapid mobili-

**Table 2. COMMON INJURIES IN BUILDING COLLAPSE**

- Dust inhalation with secondary pneumonitis
- Compartment syndrome
- Fractures, contusions, lacerations
- Hypovolemic shock (for example, hemorrhage, dehydration)
- Severe burns
- Hypothermia
- Head/neck injury with neurologic defect
- Crush Syndrome



Figure 6. Hospital building prior to demolition (Community Services Center Building of the Francis Scott Key Medical Center, Baltimore, Maryland).



Figure 7. Same hospital building in Figure 6 after demolition showing tremendous dust generation.

zation of resources in order to prevent death and minimize suffering, are best handled by local authorities (Noji 1987). Results suggest that the emergency phase for medical care of the severely injured is generally limited to the three to four days after impact. In fact, highly sophisticated medical resources that are six or more hours distant from the earthquake-affected region are of little assistance to critically-injured victims who need immediate resuscitation and stabilization.

Response time for search and rescue is absolutely critical. Observations made in Italy after the Campania-Irpinia earthquake in 1980 (de Bruycker *et al.* 1983, 1985) and the Tangshan earthquake in 1976 (Zhi-Yong 1987) show that the proportion of people found alive declined with increasing delay in extrication (Figure 8). In the Italian study, a survey of 3619 survivors showed that 93% of those who were trapped and survived were extricated within the first 24 hours. As suggested by this

### Victim Survival Rate

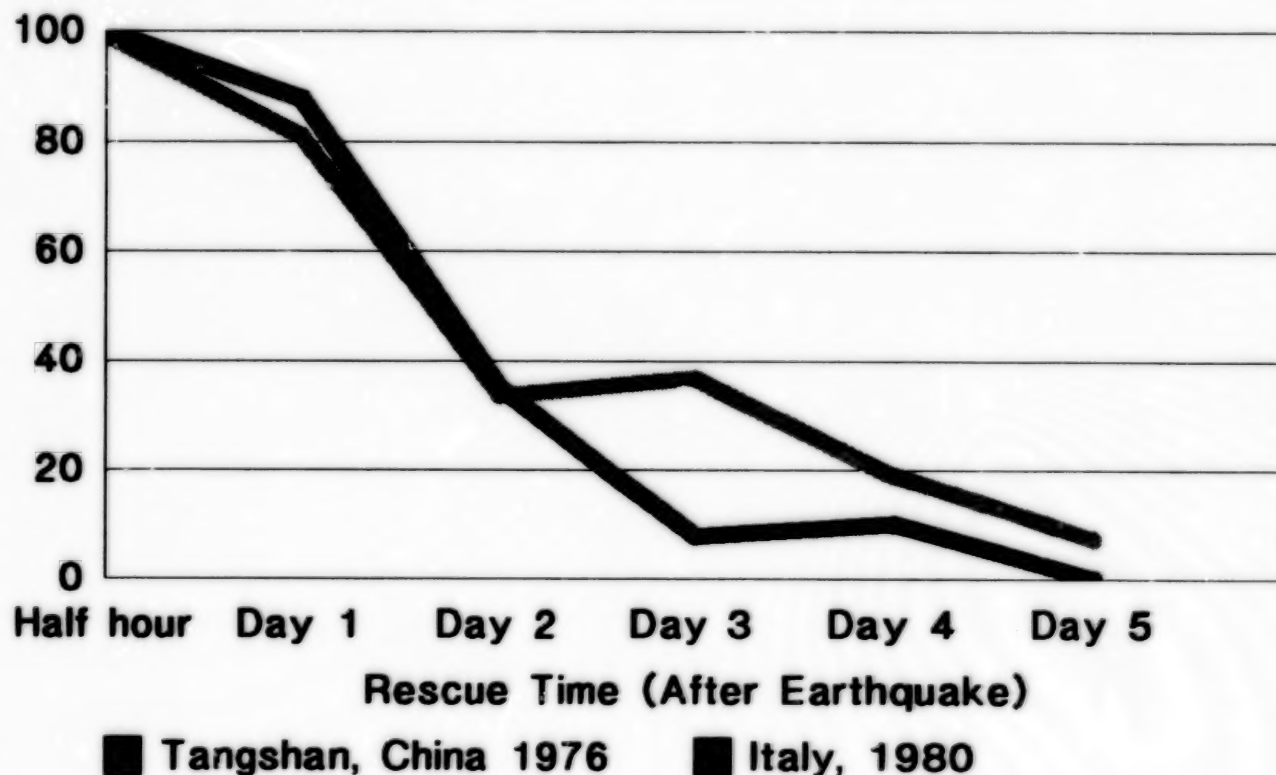


Figure 8. Victim survival rate as function of time post-impact in two earthquakes. Note declining proportion of people found alive with increasing delay in extrication.

data, if any significant reduction in earthquake mortality is to be achieved, attention should be given to appropriate search and rescue action within the first 2 days after the impact.

In the Italian study cited above, 95% of the deaths recorded were among those trapped in rubble who died prior to extrication (de Bruycker *et al.* 1985). Estimates of survivability among entrapped victims buried under collapsed earthen buildings in Turkey and China, indicate that within 2 to 6 hours, less than 50% of those buried are still alive (de Bruycker *et al.* 1983). Although it is not possible to determine whether a trapped person died immediately or survived for some time under the debris, it is undoubtedly true that more people might have been saved if they had been extricated sooner. In everyday trauma we talk about the "golden hour." For victims of building collapse, we can talk about a "golden twenty-four hours."

Thus, in any major earthquake, the bulk of the rescue effort must be planned for the first 48 hour period.

#### Medical Care for Victims of Building Collapse

When a building collapses, whether due to an earthquake, a terrorist bombing, or structural failure, a variety of challenges confront rescue/medical personnel. For those trapped survivors, there are serious problems with limb compression and dust inhalation. Some of these persons will require in-field amputation in order to extricate them. Therefore, search and rescue (SAR) combined with effective emergency medical care are essential for successful lifesaving efforts. Safar, studying the 1980 earthquake in Italy, concluded that 25% to 50% of victims who were injured and died slowly, could have been saved if initial life-saving first aid had been rendered immediately (Safar 1986).

Unfortunately, in recent major earthquakes (for example, Armenia and Mexico City), very little in the way of basic medical care was administered to persons actively being extricated from the debris (Noji 1989b). These were patients who were successfully located and accessed by the rescue personnel, however, not quite yet extricated. Very few of these patients were observed to have received intravenous fluids, stabilization of the neck with cervical collars or maintenance of patent airways. The institution of these very basic procedures, particularly intravenous fluids may very well go a long way toward reducing the morbidity and mortality related to building collapse, particularly in preventing the development of crush syndrome with its attendant kidney failure and cardiac arrhythmias.

Despite these observations, most rescue personnel are not trained in intravenous techniques (Noji 1989c). Even when trapped persons are discovered, it may take

several hours for them to be successfully extricated—plenty of time to develop severe muscle damage and secondary kidney failure.

Medical care will of necessity be austere, and conditions usually will not allow for definitive care of minor or moderate injuries. Any field medical intervention should be oriented toward life-saving extrication (for example, limb amputation), stabilization of immediate life threats (for example, maintenance of airway patency, management of external hemorrhage) and relief of severe pain.

#### TRAINING

Teams from several different countries, including the United States have been used in past heavy urban rescue operations (Krimgold 1989). Unfortunately, most of these teams had no previous heavy urban rescue experience (Table 3). This lack of experience points out the need for greater professionalization of search and rescue, better equipment, techniques and training. The ultimate goal should be the development of well-trained, highly specialized heavy urban SAR personnel, preferably located in areas of greatest seismic risk. This lack of experience strongly points out the need for comprehensive training courses in this area of heavy urban search and rescue.

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**Table 3. PROBLEMS WITH CURRENT RESPONSE TO BUILDING COLLAPSE EVENTS**

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- Untrained bystander response
  - Most SAR teams have no heavy urban SAR experience
  - Minimal medical training of SAR personnel
  - Lack of standards for heavy urban SAR
  - Lack of coordination between different teams
- 

SAR Search and Rescue

In response to this need, the Johns Hopkins University in collaboration with Virginia Polytechnic Institute have developed a comprehensive training course with faculty representing civil engineering, architecture, epidemiology/public health and emergency medicine (Noji 1989c). Topics presented in this course include:

- 1 — Causes of building collapse (for example, earthquakes, wind, blast)
- 2 — Building types and construction (for example, building typology by structural type, patterns of failure, characteristics of construction materials)
- 3 — Current state of the art in collapsed building search and rescue (for example, new developments in search and extrication techniques and equipment)

- 4 — Injury patterns observed in building collapse (for example, distribution of types of injury, morbidity/mortality time trends, crush injury/syndrome)
- 5 — Emergency medical treatment for victims of building collapse (for example, First responder responsibilities, on-site treatment/triage, transportation)
- 6 — Health considerations for rescue and EMS workers (for example, physical hazards in the unstable collapse environment, precautions regarding food and water in less developed countries) (Table 4).

### Necessary Knowledge for Effective Search and Rescue

For guiding future rescue operations, it is necessary to have information about the actual location of the victims in the collapsed structure as well as specific

details about the extrication process itself. Knowledge of collapse conditions helps set rescue priorities. The construction of a building gives some indication of the way it may collapse as the result of a blast, earthquake, cyclone, or other disaster (Figure 9). Buildings of the same class and type of construction collapse in much the same way, and common factors are present. It is important that rescuers study these factors, since this knowledge will prove helpful when extricating casualties.

For example, almost all types of damaged buildings will contain voids or spaces in which trapped persons may remain alive for comparatively long periods of time. To know where these safe places may be, it is necessary to know the characteristics of various types of construction. Victims are best able to survive in V-shaped and lean-to voids, and by searching there first, SAR personnel have a better chance of reaching survivors in time.

It is not enough to only know where to find potential survivors. Search and rescue personnel must know

**Table 4. TRAINING COURSE SCHEDULE FOR STRUCTURAL COLLAPSE EVENTS 8:00 AM – 4:30 PM**

8:00	General Introduction to the Workshop Workshop Objectives		Organization and Management New Developments in Search Techniques, Operations New Developments in Extrication
8:10	Causes of Building Collapse Earthquake Wind Blast Snow loading Poor design, detailing, construction Global Distribution of Hazards Characteristics of Hazard Phenomena (eg. earthquakes)	11:45	Discussion and Questions
8:40	Video of 1985 Mexico City Earthquake National Bureau of Standards	12:00	Lunch
9:00	Experience in Search and Rescue in Collapsed Buildings Terminology (eg. locate, access, extricate, stabilize, transport) Search Extrication Organizational Issues International Cooperation	1:00	Video of Emergency Health Care Issues from Mexico City, El Salvador and Armero, Columbia Pan American Health Organization
9:30	Coffee Break	1:30	Injury Patterns Following Major Events Involving Building Collapse Distribution of Types and Severity of Injury Injury outcome characteristics Characteristics of Affected Populations Distribution of Injuries Globally Relationships of Disaster Agent, Response Morbidity and mortality time trends Information on deaths and hospitalizations to evaluate selected factors that may influence why some people die from their injuries, while others do not.
9:45	Building Types and Construction Materials Building Typology by Structural Type Patterns of Failure (eg. foundation failure, low rise, larger structures). Characteristics of Construction Materials (eg. steel, concrete, reinforced concrete, masonry, timber). Properties of Structural Materials (eg. strength, ductility, fatigue life). Structural Elements (eg. beams, columns, slabs, walls)	2:30	Coffee Break
10:15	Current State of the Art in Collapsed Building Search and Rescue Mexico City San Salvador Bridgeport Brownsville Equipment and Uses	2:45	Emergency Medical Treatment for Victims of Building Collapse Mass Casualty Management Typical Injuries of Building Collapse Victims First Responder Responsibilities (Access, extrication, stabilization, BCLS, BTLS) On-site treatment and triage Transportation of victims Crush injury syndrome Treatment of hypothermia Health considerations for rescue workers
		3:45	Discussion and Questions
		4:00	Panel Review and Summary Research Needs Relationship of Research to Improved Search and Rescue Practice
		4:30	Conclusion



Figure 9. Main street in devastated Armenian village showing complete collapse of all buildings. Note complete collapse of precast-concrete frame school building on right side of street. These were particularly lethal to occupants.

what to do once these persons are located. They must have some knowledge of what specific types of injuries to expect as well as how to estimate relative injury severity and prognosis. The latter is essential for effective triage. Severe dust inhalation with resultant pneumonitis is an important problem for victims of building collapse. Therefore SAR personnel should be well-versed in techniques of airway management and oxygen administration. Optimally, they should know how to start intravenous lines and administer life-saving fluids and medications. They must also be able to recognize and treat problems of prolonged limb compression such as compartment syndrome and crush syndrome. These conditions require immediate attention and cannot wait until the victim has been completely extricated and transported to a treatment area.

Efforts to remove occupants from a collapsed building may expose rescuers to more dangers than are faced by the victims. Rescue personnel must constantly observe all safety precautions to protect themselves from injury. For example, the destruction of buildings and industrial facilities by any catastrophe will invariably result in ruptured electrical, water, gas and sewer lines (Figure 10). Other hazards will be escaping gases and chemicals used in refrigeration units and in certain industrial operations. These utilities create serious problems for casualties and rescue personnel. Each person on the team must be knowledgeable regarding these potential hazards and trained to be alert to any change in conditions at the collapse site that could raise an additional threat to their safety. Rescue personnel should also be instructed in the proper method of shutting off water, gas and electricity and informed of the probable locations of shutoff valves and master switches.

Unfortunately, it is difficult to develop and practice search and rescue techniques and medical care for victims of building collapse. During a major disaster such



Figure 10. Collapsed school building in Armenia with broken water, gas pipes and live electrical wiring demonstrating hazards to occupants and rescuers.

as an earthquake or even at a single building collapse site, concentration is usually focused on maximizing the capabilities of existing SAR techniques. Little or no time is available for enhancement or experimentation with new ideas and equipment. The comprehensive training course described above attempts to address some of these difficulties in a positive and practical way.

## RESEARCH PRIORITIES

In addition to addressing the problem of heavy urban search and rescue in a unique multidisciplinary manner, we hope to spawn new research into both search techniques and rescue methods (Table 5). For example, a systematic comparison of the many existing techniques of search and rescue is underway, including a controlled evaluation of SAR equipment (for example, efficacy of dog teams, remote sensing equipment, portable seismographs, bore-hole cameras, infrared detectors, carbon dioxide sensors, etc). Our research is also looking at the functional requirements of search and extrication devices, including the development of performance specifications for devices which will penetrate a collapsed structure to detect or reach a victim.

There is also a need for a sound research program on medical affects of earthquakes, particularly with regard to injuries and deaths following building collapse

Table 5. RESEARCH NEEDS

- Search and rescue tactics
- Search and rescue strategy
- Refinement of data collection methodology
- Development of needs assessment/evaluation tools
- Injury typology and severity
- Treatment of Crush Syndrome

(Jones *et al.* 1989). As mentioned above, our multidisciplinary team is coordinating research activities from both the engineering, epidemiology, emergency medical, and search and rescue perspective.

Unfortunately, the current knowledge base of the precise causes of deaths and injuries in building collapses is not well developed, resulting in often misdirected provision of relief services as well as inadequate community medical/health planning for earthquakes (Kates *et al.* 1973; Saidi 1963; Whittaker *et al.* 1974).

In most past earthquakes, very little data has been collected concerning the actual victims themselves (for example, location in the structure, type and severity of injuries, post-rescue behavior, etc.) (Lechat 1974; Glass *et al.* 1977). It is therefore difficult to adequately plan search and rescue activities, proper medical care and to effectively request appropriate outside aid.

### **HIGH PRIORITY RESEARCH AREAS**

#### **Epidemiologic analysis of risk factors for deaths and injuries**

Thousands of persons have been killed as a result of the earthquakes during the past decade. The specific mechanisms of death and injury in building collapse clearly need much more extensive study (Noji and Sivertson 1987; Alexander 1985). In particular, very little is known as to what distinguishes those who survive from those who do not (de Bruycker *et al.* 1985). The morbidity (injuries) and mortality (deaths) resulting from the recent earthquake in Soviet Armenia were clearly related to structural factors, search and rescue activities, evacuation procedures, and medical relief action in the immediate post-disaster phase (Noji 1989a). For example, the possibility of escape was crucial for survival and depended on the type of building and occupant behavior (that is, running out of the building decreased casualty rates in certain situations).

Early work by epidemiologists has produced an indication that research on risk factors for building collapse-related fatality and injury might benefit from more disciplined study (de Ville de Goyet *et al.* 1976; Glass *et al.* 1977). Such research will have direct implications on the rescue-relief activities and the medical supplies that will be required.

#### **Earthquake Injury Epidemiology**

Basic knowledge of the type of injuries and illnesses caused by earthquakes as well as the severity of such injuries is also essential to determine the appropriate relief supplies, equipment and personnel needed in similar situations (Alexander 1985; Ortiz *et al.* 1986).

Unfortunately, existing data from past earthquake events has not been systematically collected with the intention of improving our understanding of injury and illness patterns and improving survival rates (Binder and Sanderson 1987).

#### **Information Necessary for Immediate Needs Assessment in Earthquakes**

Currently, the data on damages collected in earthquake events are usually crude estimates based on superficial observations of limited technical and statistical validity (Guha-Sapir and Lechat 1986b; Noji 1987). There are currently no standardized methods or indicators to rapidly determine the health needs of earthquake victims and communities. Research into the exact nature of immediate needs in terms of trauma, injury (fatal and non-fatal), and mortality together with their relationship to structural and demographic factors of the community and physical circumstances of entrapment would, therefore, make a significant contribution toward a cohesive earthquake preparedness plan for community education, needs assessment for relief aid, public worker training for emergency need, and appropriate rehabilitation programs (Osawa 1987; Coburn 1987).

#### **Management of casualties**

Research needs to be conducted on the medical management of casualties resulting from earthquakes (for example, perfecting triage techniques, determination of resuscitation potentials). More effective interventions to prevent or to effectively treat these conditions must be identified (for example, treatment of crush syndrome) as well as to minimize disability (for example, amputations) (Kunkle 1989). The average period of time elapsed between discovery of a trapped person, extrication, on-site medical care, evacuation and arrival at hospital is a decisive factor, study of which can deeply influence future relief operations (Noji 1989a).

#### **Medical supplies**

In several past major disasters there were major problems in identifying, selecting and distributing large quantities of unsolicited donated medical supplies, food and clothing. Operational research is needed to determine what medical supplies are:

- Actually needed (based on number and nature of injuries and standard acceptable treatments).
- Most commonly requested at local and national levels.
- Provided by the national or international community.

## Disease control and sanitation

The question of the actual risk of increased disease transmission following earthquakes requires extensive, current and retrospective field study (Alexander 1982). The effectiveness of disease control measures and the techniques of epidemiological surveillance are areas of considerable practical interest (Binder and Sanderson 1987). Although outbreaks of food or waterborne diseases (for example, cholera, typhoid) have not been a major problem in recent earthquakes (for example, Armenia, Mexico City), the public is usually very concerned regarding epidemics and encourage the implementation of a mass immunization program against typhoid as well as tetanus (Ortiz *et al.* 1986; Zeballos 1986). In past earthquakes, the public has also been worried regarding the possible transmission of disease from decaying corpses. This has never been documented to be a major public health problem in any past natural disaster unless the bodies were already infected with organisms known to be transmissible through contact with bodily fluids (for example, hepatitis, tuberculosis).

## External relief

The effectiveness and/or problems associated with the influx of large quantities of relief supplies and relief personnel from outside the affected area need to be studied thoroughly and the results disseminated. Studies of the role of outside medical volunteers following earthquakes will hopefully settle the controversy of their usefulness and provide the public health authorities and medical associations with guidelines and criteria for a constructive approach. Large numbers of external relief workers may place an added burden on local resources for food and lodging. Many outside relief workers may be unable to speak the local language or lack specific skills necessary for field management of the injured.

## CONCLUSION

In summary, the following points should guide medical planning for earthquakes:

- 1 — Earthquakes are a distinct threat in parts of the U.S. Midwest and East Coast, as well as along the Pacific Coast that contain dangerously under-designed buildings.
- 2 — "First responders" after an earthquake will be relatively uninjured survivors- friends, and relatives of the victims.
- 3 — Virtually complete dependence by the public on professional health personnel to provide emergency medical care (for example, paramedics).

- 4 — General knowledge of life-saving first aid procedures and personal survival techniques among the population is generally low (approximately 5%).
- 5 — Survival opportunity for most victims of building collapse generally limited to 24-48 hours. Exceptional cases have survived for over two weeks.
- 6 — Epidemics and need for mass immunizations rarely necessary following earthquakes.

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# THE HYATT-REGENCY HOTEL DISASTER

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## AN OVERVIEW

The Hyatt-Regency Hotel, located just south of the downtown area of Kansas City, opened its doors to the public in July, 1980. One year later Kansas City's newest luxury hotel was the scene of a disaster that shocked the city. Just after 7:00 p.m. on Friday, July 17, 1981, the tragedy, which would become known as the Hyatt Skywalk Collapse, unfolded. One hundred and thirteen people died, 188 persons were injured and an estimated 5,000 lives of relatives and rescue workers would be affected.

The Hyatt-Regency Hotel hosted a series of dances over a period of several months prior to the skywalk collapse. These dances, known as Tea Dances, had become a popular event, with an estimated 1,500 people in attendance on the night of the collapse. The people attending this dance represented middle class America. A large number were native citizens of Kansas City who came to the dances to dance and listen to the "big band era" music played by the Steve Miller Band.

A dance was underway, with guests filling the first floor dance, lobby, lounge and the Terrace Garden dining area. Suspended from the ceiling were three skywalks located on the second, third and fourth floors which connected the main hotel building to the exhibition hall. All three skywalks were suspended directly over the dance floor and the front lobby to the hotel. The third floor skywalk was offset and separate from the second and fourth floor skywalks. The second floor skywalk was attached to the underside of the fourth floor skywalk.

People interested in watching the Tea Dance below had congregated on the skywalks. An estimated 50 people were on the fourth floor skywalk and it is estimated that about 100 people were on the second floor skywalk. Witnesses reported later that some of the people on the skywalks were dancing and moving in rhythm with the music of the Steve Miller Band, playing below. Directly under the skywalks, an estimated 150 people were either dancing or watching the dancers.

At 7:05 p.m. the second and fourth floor skywalks separated from the holding rods which anchored them to the ceiling, spilling some of the people who had been

standing on the skywalks, and then collapsing onto the lobby and dance floor.

Fire and police dispatchers received the calls at the same time. The first caller to the police department was an off-duty police sergeant who told the dispatcher that a skybridge had collapsed and 50 to 100 people were trapped.

Responding fire units would later report that they initially thought they had a fire in the lobby because the dust in the air looked like smoke as they arrived. In the confusion that met the first responding fire and police personnel, injured people were observed, some walking and others lying down. They also observed persons trapped in the debris, some were alive and others obviously dead. At that time it was unknown how many other living and dead persons were trapped in the debris. The first arriving police sergeant, shocked at what he saw in the lobby, reported that an individual grabbed his arm and said "I'm a doctor. What do you want me to do?" We would learn that the Tea Dances were frequented by many of the off-duty medical personnel from the three hospitals located nearby.

The fire department would be committed to the incident for 24 hours and the police department for 45 hours. The incident lingered in the minds of the public and the media and the courts until 1988 when a civil suit, brought by the State of Missouri, settled responsibility for this tragic event.

## INCIDENT COMMAND

Although Kansas City had experienced a tornado, an aircraft crash, a large scale civil disorder, and flooding incidents in the history of some of the command level personnel who responded to the Hyatt-Regency Hotel disaster, we had not experienced a major heavy rescue incident. Further, no pre-arranged incident command agreement or training existed prior to this incident.

Absent the existence of an incident management system an ad hoc organizational structure for the responding agencies began to form between the arriving agencies. This was accomplished awkwardly at first. Without

designating one agency as being in charge, the ad hoc organizational structure addressed the functions that had to be set in operation in the following manner: the heavy rescue operation was managed by the fire department and members of the heavy construction industry; the medical treatment and transportation of victims would be coordinated between the fire department, Kansas City Area Hospital Association, and the Metropolitan Area Service Trust (MAST); physical security and perimeters would be managed by the police department; body recovery and processing would be handled by the Jackson County Coroner with the assistance of the police department; and handling the media was a joint cooperative effort between the fire department and police department.

In retrospect, one of the training topics that needs to be addressed with first responding personnel is how they link together to cooperate in a rescue effort and what goals or priorities need to be addressed. For example, although the front drive and the street in front of the hotel quickly filled with unattended emergency equipment, the first two police commanders succumbed to the cry for help by injured persons and helped carry an injured lady from the lobby area. Rendering personal assistance to injured persons was repeated many times during the first hour of the incident.

An arriving police major noted the lack of traffic flow and designated a police sergeant to open an entrance and exit route for the movement of emergency equipment, telling the sergeant to use tow trucks if necessary to move vehicles. The primary mission for police personnel at this point in time should have been to support the life-safety activities by ensuring the free and unobstructed movement of human rescue personnel and equipment into the site and the movement of ambulances carrying victims away from the site. Once these routes are operational, police personnel can assist, if needed, in other activities on site.

The highest priority in disasters is life-safety and all emergency response agencies should support life-safety activities first. The second priority has to do with property conservation and the last with recovery efforts. The priority of goals should dictate not only which agency should be the lead agency in an incident but also which activities need to be addressed and in what order. Training personnel in this concept will facilitate the integration of and cooperation between resources during crisis.

Another example emerged when some construction workers left the site to get equipment and experienced difficulty getting back into the perimeter. Police officers, obeying instructions to isolate the area, would not let them back into the site. The issue of who could or could not gain access through the police perimeter caused a pass system to be established for the duration of the incident. Although the problem was corrected it remains

an important lesson. Police personnel need to understand that individuals with special knowledge or skills will require access into an isolated area.

### **Recommendations**

- 1 — Develop an incident management system in your jurisdiction and train personnel in its implementation.
- 2 — Ensure all responding personnel understand the priority of goals (life-safety activities first, property conservation activities second, and recovery activities last) and their agency's contributions in achieving those goals.
- 3 — Ensure adequate communication exists between disciplines and agencies to quickly identify and correct problems.

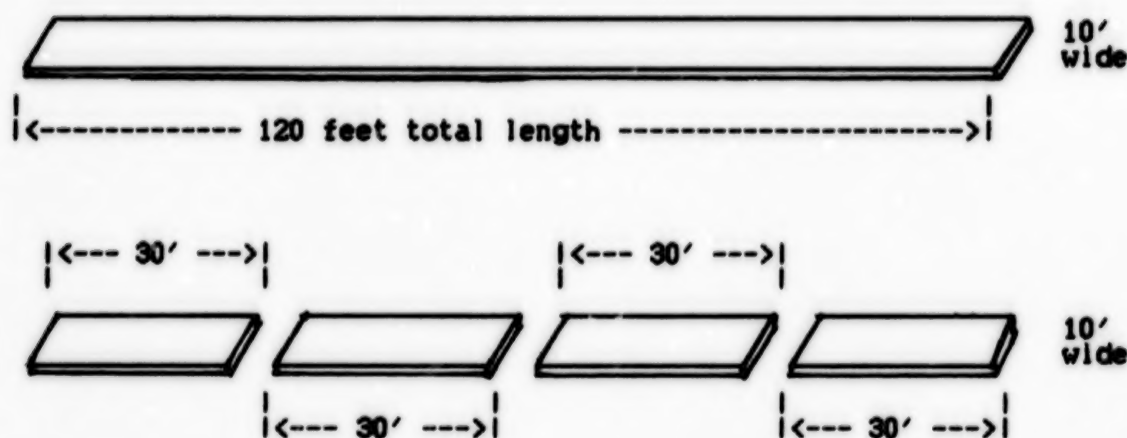
## **THE HEAVY RESCUE OPERATION**

### **The Mechanical Problem**

To have a good understanding of the rescue and body recovery effort that took place on the night of July 17, 1981 we need to understand the mechanical problems created by this structural collapse. Foremost in considering the impact of this incident on rescue personnel is that none of the responding personnel had been previously involved in a structural collapse incident. Second, the sheer weight of the skywalks posed a major problem. Each of the three skywalks was constructed the same. They were 10 feet wide and 120 feet long (Figure 1). Each skywalk consisted of four sections, each section 10 feet wide and 30 feet long. The fourth floor skywalk fell almost perfectly onto the second floor skywalk.

The skywalks consisted of 4 inch concrete caps over two (2) I-beams. Within the space between the I-beams and under the concrete caps was a hollow space which carried electrical conduit and a water line for the fire fighting water system. Under the skywalks, decorative ceiling material was placed to cover the conduit and water pipes.

The collapse severed the fire fighting and water sprinkler lines, venting water onto the floor of the lobby. Having no drains to remove the water, the level began to rise. In some locations the water ranged from 4 to 6 inches deep. On the south end of the lobby, one person was trapped face down on the lobby floor. Concern rose that persons were trapped face down under the skywalks and would drown in the rising water. The fire department ordered the water line serving the fire fighting system shut off. Almost 30 minutes lapsed before the standpipe fire fighting system drained from this 42 story building. Shutting down the standpipe fire fighting sys-



#### Weight Information:

Total weight of each skywalk: 30 tons  
 Weight of each 30' section: 7.5 tons

Both skywalks together represented 60 tons on the lobby floor.

Figure 1. The diagram depicting the skywalks at the Kansas City Hyatt Regency Hotel.

tem meant that the fire department would be severely limited in any effort to suppress a fire in the upper portions of this large structure.

Access to the collapse site was limited to an approach from the west side. The Exhibition Hall was on the south side and the hotel building was to the north. On the east side, the Terrace Garden area was elevated an estimated 15 feet higher than the lobby floor; and further to the east, outside the building, was a grassy area. The only approach for heavy rescue equipment was from the main drive.

During the first hour, an individual approached the perimeter, announcing that he was an architect and was involved in the design of the Hyatt-Regency Hotel. He told command personnel that the hotel was in danger of further structural collapse. Although a genuine architect, the individual's claim that he was involved in the design of the hotel was later discovered to be untruthful.

#### The Rescue

Beyond the visibly trapped, rescue workers were unaware of how many were trapped inside and under the skywalks and the weight of the skywalks. Other than calling for heavy equipment, on-site personnel did not know what types of heavy equipment were needed. It was crucial to get construction industry personnel, heavy equipment operators and engineering and architectural professionals to the site.

Operation Bulldozer was put into effect. Under this plan the construction industry would provide the personnel and equipment necessary to conduct a heavy rescue free the first 24 hours. After that, only actual costs would be charged to the city. The professional and skilled construction industry personnel who answered the call to assist would perform with remarkable dedication during the duration of the rescue effort.

Construction workers working on a project across the street from the Hyatt-Regency Hotel and from their union hall responded to the site to volunteer their desperately needed skills. Heavy construction equipment began rolling in from a variety of points throughout the metropolitan area. Police motorcycle officers were sent to conduct emergency escorts for some heavy equipment from one location to the heavy equipment staging area.

One of the first problems for the rescue effort was access into the damaged area. The closest position from which heavy rescue equipment could be brought to lift the skywalks was by way of the front drive. Access from the front drive into the lobby area was made through a double set of brass turnstile doors. These doors were the closest entrance of any width to the damage area. In the initial effort to get equipment, including a heavy forklift, into the site, a one-half inch steel cable was wrapped around these brass doors and they were pulled out of the front of the building. The lobby area lighting system was connected to the brass doors. When the doors were pulled out, the electricity serving the lobby was shut off. Res-

cue personnel requested portable lighting and generators.

The use of gasoline powered rescue equipment and portable lighting caused a build-up of exhaust fumes and contributed substantially to the noise in the lobby area. To improve ventilation in the disaster site police personnel were assigned to break out the large plate glass windows located on the mezzanine level with the Garden Terrace on the east side of the hotel. Persons on the lobby floor, close to the collapse area found it increasingly necessary to yell louder and louder at people near them in order to be heard. One fire commander had to use a bull horn to direct personnel in his immediate area.

The fire department's Hurst tools would prove effective in lifting portions of the fourth floor skywalks to extricate trapped persons but they could not lift the second floor sections with the fourth floor sections still on top of them. Arriving construction engineers and equipment operators worked closely together with rescue personnel to minimize risk to those involved in the operation. One 30 ton and two 50 ton cranes were brought to the site. The 30 ton crane was moved to the glass facade of the hotel and its head punched through the glass, so it was located over the fourth floor slab which was partially caught on the second floor ledge. The intent was to anchor this slab, preventing it from coming loose and shifting the remaining fourth floor sections of the skywalk, further risking the lives of trapped persons or the rescue workers.

The two 50 ton cranes were then moved to the front of the building, and the crane heads punched into the glass facade of the building. From that point both cranes could work together to lift the sections of the skywalk. The heavy rescue operation was a series of steps involving the separation of the skywalk sections, lifting them, removing living victims, moving the sections aside and setting them down, and recovering the bodies of the deceased. This process was repeated until all sections of the skywalks had been moved.

### **Evacuating The Hotel**

Shutting off the fire fighting and water sprinkler system, coupled with the increased fire hazard caused by sparks generated from rescue equipment, resulted in a meeting between the fire and police commanders and the manager of the hotel. Following this meeting the hotel was ordered evacuated. The Hyatt-Regency Hotel staff arranged and paid for the relocation of hotel occupants to other hotels in the area.

Conducting an emergency evacuation of a 733 room hotel meant the issue of securing the personal property of the evacuees would have to be addressed. An agreement was reached between the police department and the

hotel security staff for one police officer and one hotel security officer to open each room, inventory the contents, leave a copy of the inventory form inside the room, lock and place a seal on the door and to turn the original of the inventory form into the police command post. Once the situation was stabilized and the dangers under control, those evacuated were permitted to return to the hotel to collect their property. They would be escorted to their room, the contents of the room rechecked against the inventory form, and the owners would accept custody of the property by signing the inventory form. This process was very successful. Only one item of personal property reported to have been left in a hotel room was reported missing.

### **Recommendations**

- 1 — Develop an agreement with the construction industry in which heavy rescue personnel and equipment can be accessed when an incident occurs.
- 2 — Address the issue of getting construction industry personnel and equipment to the site as soon as possible. This means providing emergency escorts by police vehicles and by providing procedures and instructions which would permit the responding operators and construction industry professionals to enter the perimeter without undue delay.
- 3 — Train emergency service personnel to identify a staging area for heavy rescue equipment which can handle the size and weight of the equipment that will respond.
- 4 — Develop a pass system which can be used in any emergency and would facilitate the entry of professional and skilled individuals into an isolated area.

### **EMERGENCY MEDICAL SERVICE**

The Metropolitan Ambulance Service Trust (MAST) was at peak staffing on this Friday night. When the collapse occurred all 16 on-duty ambulances and 15 mutual aid ambulances from surrounding jurisdictions were mobilized.

MAST protocols require the first arriving ambulance to assess the impact of the incident and advise their communications center of that assessment. Once determined to be a mass casualty incident, the Kansas City Area Hospital Association (KCAHA) alert plan was put into effect. A central coordination center, located at Baptist Memorial Hospital, was opened and all hospitals were alerted that a mass casualty incident had occurred.

Each hospital was required to report the status of emergency service personnel and facilities and the number of beds which were available.

The first ambulance at the scene established the initial triage location in the front drive of the hotel. Arriving ambulances would receive casualties, stabilize them, advise communications that they were ready for transport and receive the name of the hospital to which the victim would be transported. As night fell the triage area was moved into the west end of the convention center, located south of the lobby floor.

A staging area for ambulances was established at an intersection just south of the hotel. Once the person in charge of medical staging received a request for a certain number of ambulances, they were released to enter the isolated area, pick up their passengers, and were routed to a hospital. Central control over the release of an ambulance from the staging area to pick up a victim was maintained by the MAST command post.

On the lobby floor, the doctor in charge of the triage operation worked closely through the night with rescue personnel. Periodically, personnel were instructed to keep quiet while some rescuers moved along the collapse area trying to locate trapped persons who could talk. Locations where contact could be made became the focus of attention. Construction workers using jackhammers would cut holes into the four inch concrete caps near the locations of trapped persons. On several occasions, the triage doctor would slip into the holes to treat trapped injured persons. Later, he would admit that he had to cut through some dead persons to get to and treat living victims. This dedicated doctor would also later admit that he suffered serious post-incident problems as a result of his duties at the scene of this incident.

An immense outpouring of support for the rescue effort resulted in an appeal by the police department for citizens to donate blood. The blood bank was not notified that the community had been encouraged to donate blood and, as a consequence, was not prepared for the 2,200 persons who showed up the following morning (Saturday) to give blood. The crowd of donors was so large that police traffic units had to be sent to the blood bank to direct traffic. Four hundred and fifty units of blood were actually used for Hyatt victims.

### **Staging Rescue Personnel**

Another observation having to do with the noise on the lobby floor was made following the incident. Although not obvious until reviewing photographs, the staging of stretcher teams or other rescue personnel not actively performing a mission at the rescue site contributed to the noise and confusion. We also believe that less control is exerted over staged personnel if they can see

the site because they will have a tendency to move closer to the action. The last consideration has to do with the effect of extending the exposure of rescuers to the human carnage in these incidents and the possibility of that contributing to their having post-incident problems. Whenever possible, the exposure times should be kept to a minimum.

### **Casualty Statistics**

The final report on the emergency medical service community's response to the Hyatt disaster is impressive. The medical community performed excellently in this first test of their mass casualty plan. The Kansas City Area Hospital Association plan was later adopted by metropolitan Washington, D. C. after the crash of the Air Florida jetliner into the Potomac River the following year.

As a result of the mass casualty plan's implementation no surgery facilities were overloaded. Other significant statistics are listed as follows:

#### **Deaths:**

- 108 dead at the scene
- 3 died later that night
- 2 died later.
- 113 total deaths

#### **Major Injuries:**

- 90 admitted to hospitals (Five persons died later that night or following admission.)

#### **Minor Injuries:**

- 103 minor injuries
- 188 persons were transported after medical treatment.
- 17 area hospitals were used. (Three of the hospitals were within 5 minutes of the site.)

#### **Medical transport conducted by:**

- 31 city mutual aid ambulances
- 1 city bus
- 1 medical transport helicopter

An unknown number of injured persons were transported to hospitals by taxicabs. The taxi drivers transported these victims and did not seek reimbursement.

### **Recommendations**

- 1 — Pre-arrange emergency resupply of spineboard, stretchers, and narcotics with medical supply sources.
- 2 — Coordinate with affected outside agencies before requesting that citizens volunteer blood or any services to the operation.
- 3 — Unless impossible to do otherwise, avoid staging personnel within sight of the in-

cident. Keeping them out of sight of the incident will reduce the noise and confusion at the site, maintains better control over them as resources, and reduces the chances of their having post-incident problems.

- 4 — It was suggested that all ambulances that may be involved in a mutual aid response position their equipment and supplies in the same locations onboard the vehicles. Doing this would save considerable time when a paramedic is sent to another vehicle to obtain equipment or supplies.

## BODY RECOVERY

The most significant difficulty facing the personnel managing the body recovery and processing operation was that the community did not have a mass body recovery procedure. In the absence of such a procedure, an ad hoc procedure was established. Figure 2 shows the rate of body recovery by hour.

### Establishing A Temporary Morgue

A florist convention was being held in the convention center, just south of the lobby area. The area had

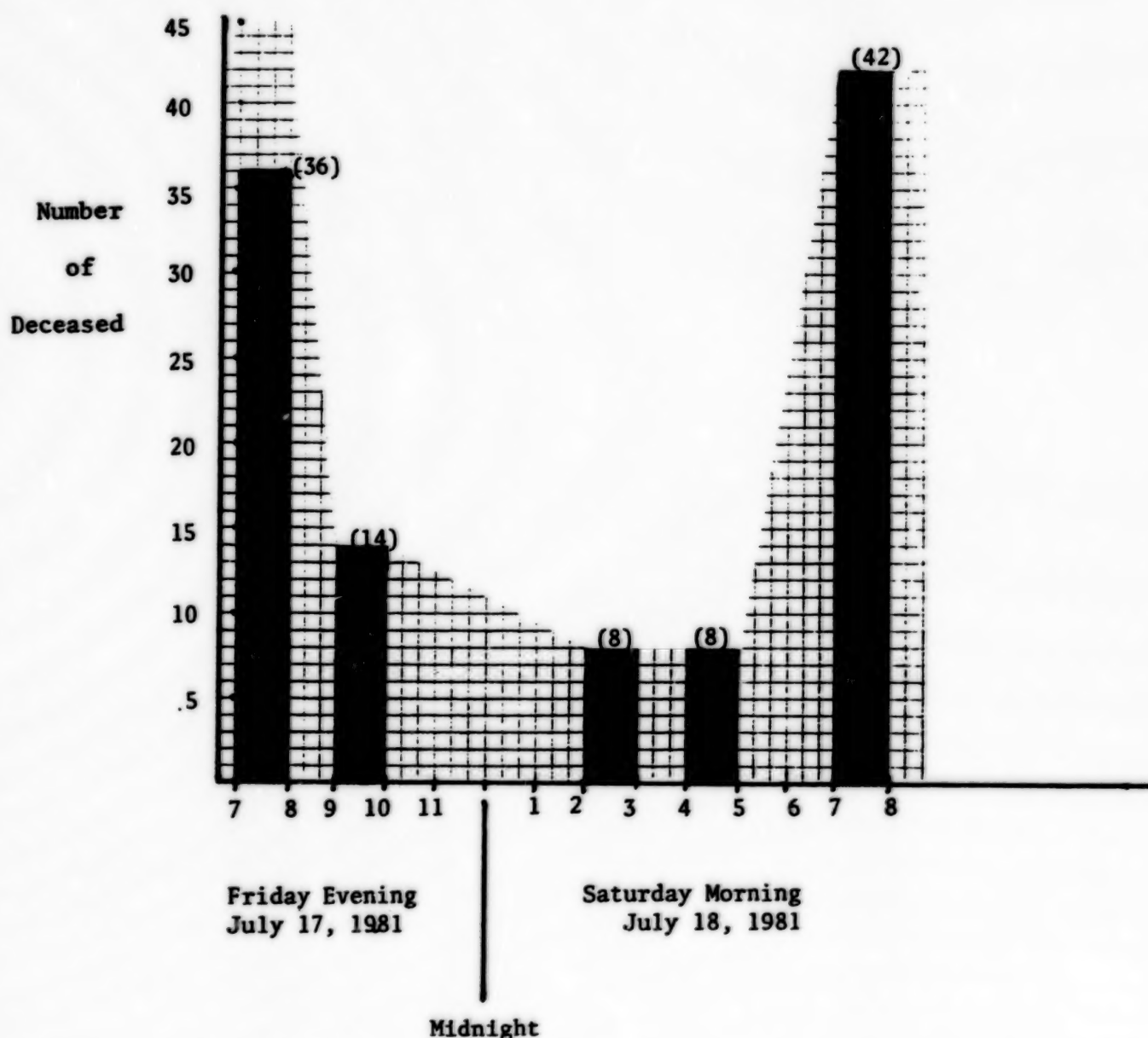


Figure 2. Hyatt Regency Disaster. Times of initial recovery of dead bodies.

tables and cloth dividers set up, making it a good location for a temporary morgue. Crimes Against Persons Detectives and Crime Scene Investigators were selected to staff the temporary morgue.

The process of recovery and processing recommended to the Jackson County Coroner was as follows:

- 1 — Photograph the body where it was found. Body Control would issue a number for the body and it would then be removed to the temporary morgue.
- 2 — At the temporary morgue the body would again be photographed, the body number verified, and personal effects of value recovered.
- 3 — If the body carried identification, the body would be released to a local funeral home, pending relative identification.
- 4 — Those bodies for which identification was questionable would be transported to the County Morgue.

The coroner, also acting without a mass body recovery and processing plan, refused to release any bodies to funeral homes without being processed through the county morgue. The county morgue was designed to hold a maximum of 35 bodies. The first hour into the incident produced enough bodies to fill the county morgue to capacity. Consequently, bodies were stacked like cordwood in the hallways of the county morgue.

The temporary morgue became operational approximately one hour into the incident. The personnel assigned to it worked continuously and without a break until the last body was transported to the county morgue the following morning. One of the most immediate logistical problems was locating enough body bags to handle the dead. In the police department's communications unit one dispatcher was assigned to make telephone calls to local sources of body bags. This effort took most of the dispatcher's eight hour shift.

On Saturday, July 18, 1981 the Federal Bureau of Investigation offered the services of its national fingerprint files to assist in the identification of victims. While this was not required, the FBI fingerprint files can be an invaluable resource for an agency.

As of Sunday morning, July 19, 1981 five victims remained unidentified — all females. A contributing factor was that men carried identification on them in a billfold, whereas women left their purses on the table when they got up to dance.

#### **Relative Notification And Body Identification**

A Relative Notification Unit was established at a police facility within four blocks of the hotel. Personnel at this location would attempt to contact relatives of the

deceased, who would be requested to respond to the police facility. From the Relative Notification Unit the relative(s) would be escorted to the County Morgue to confirm the identity of the deceased. Because the number of bodies exceeded the storage and viewing space of the County Morgue, escorting officers had to sort through the stacked body bags to locate the body of the relative for identification. This became an embarrassing process to be involved in because no dignity was shown for the bodies of the deceased victims.

Two problems were noted in the relative notification operation. The first was that the police facility lacked an adequate number of phone lines to handle the volume of incoming and outgoing phone calls. One supervisor commented that we should have requested installation of additional temporary lines. The second problem dealt with the handling of relatives. To say that police personnel found this task difficult would be an understatement. We were unaware that the American Red Cross can provide nurses trained in helping relatives called upon to identify deceased loved ones.

#### **Recommendations**

- 1 — Develop a mass body recovery and processing procedure before an incident occurs.
  - a. In all mass casualty incidents the Coroner or Medical Examiner should respond to the site for the purpose of assessing where and how the deceased victims should be processed.
  - b. If governmental facilities cannot handle the number of bodies being processed, attempt to handle as much of the processing at the temporary morgue as possible. Refrigeration will become a serious concern over a period of time. Access to portable refrigeration, such as refrigerated trucks, may be crucial in a mass loss of life incident.
  - c. Select the personnel who'll be involved in body recovery and processing carefully. Whenever possible, use personnel whose normal duties involve the handling and processing of deceased persons.
  - d. Establish and enforce a schedule of breaks for morgue personnel. Regardless of their dedication to the process, all personnel should be given regular breaks from morgue duties.
  - e. Meticulously document and photograph the location and conditions under which bodies are found.

- f. Establish rigid controls over the process of issuing numbers for recovered bodies and releasing the names of victims to the media. Under no circumstances should the names of the victims be released prior to notification of relatives.
  - g. Attempt to locate a Relative Notification Unit in a facility that has adequate phone lines to handle the volume of out-going and incoming calls that will be necessary.
- 2 — Take advantage of those agencies which can provide nurses or other professionals who can assist in dealing with relatives who are called to identify loved ones who have died in these tragic incidents.
  - 3 — Predetermine those supply sources which can provide large quantities of body bags.

### **MEDIA**

Prior to the collapse a local television station was video taping the Tea Dance, but at the time of the sky-walk collapse the camera person had turned the video camera off. Once turned on the camera provided the only record of what the collapse area was like immediately following the incident.

The massive response of international, national, and local media had not been previously experienced in Kansas City. A media assembly area was established to the immediate north of the lobby drive and just outside the pedestrian perimeter. From this location the fire and police departments coordinated and held regular media briefings.

The media had two major thrusts of inquiry: the number and names of victims and access to the site for the purpose of photographing or videotaping the collapse area. Inquiries about the names of victims, whether coming from the media or the public, flooded the fire and police communications centers. Continuing concern over ensuring relatives were notified of the loss of a loved one caused great caution in the process of releasing the names of victims. At the same time the media directed relentless pressure in its efforts to obtain those names. We are not aware of any instance in which the media obtained the name or names of the deceased before relatives were notified.

Although members of the media never relented in their demand for access to the site itself, they remained respectful of the rescue effort. On the following morning, after all bodies had been located, a meeting was held between the fire department, police department and the management of the hotel. The hotel was considered not

only as private property but it was still a site in which an investigation would be on-going to determine the cause of the collapse. During this meeting it was decided that a tour would be conducted for the media, but that tour would not permit them onto the lobby floor. To the east and a half floor above, overlooking the collapse site, was the Terrace Garden Restaurant. This location would permit the photographs and a better briefing on the rescue which the media wanted. Media personnel were escorted by the police department to the Terrace Garden Restaurant and a full up-to-date briefing was given. Interviews and photographs were also permitted from any location on the level.

### **Recommendations**

- 1 — Establish a location where citizens and the media can call, other than the fire and police communications units, for information concerning the names of victims and locations to which the injured have been taken.
- 2 — Ensure the early identification of a media assembly area in critical incidents and ensure trained personnel respond to address the needs of the media.
- 3 — Designate certain personnel to work with the media, coordinated by only one person. That person can clear others to speak to the media, but only after agreements are made about what will be discussed. The purpose of doing this is to reduce the opportunity for conflicting information being released to the media and avoid the chance that victims names will be released before relatives are notified.

### **POST-INCIDENT COUNSELING**

After the cessation of the Hyatt-Regency Hotel rescue operation, personnel who were involved in the incident were told they could participate in post-incident counseling. The counseling would be voluntary and would be offered at no cost to the personnel attending. Several of the fire service commanders did attend these sessions, hoping to set a positive example to their fire fighters. With the exception of the fire commanders, fire fighters and police officers did not attend the counseling sessions.

At the time of the Hyatt-Regency Hotel disaster little was known about Critical Incident Stress and its effect on rescue personnel. What is known is that several ranking fire commanders chose to voluntarily retire within a short time after the incident. One commented that he would not want to be a part of that type of an incident if

it were to occur again. A substantial number of emergency service personnel were exposed to the terrible carnage on the lobby floor and were not properly dealt with after the incident. Comments were heard from Viet Nam combat veterans who indicated they had never seen combat deaths with as much damage to the bodies as a number of the Hyatt victims had.

In the immediate period following the skywalk collapse, Kansas City was not prepared for the impact of this incident on the community itself. It was later reported that an estimated 5,000 lives were affected by this incident. Unlike an aircraft crash where most or all of the victims are strangers to the community in which the crash occurs, the majority of the victims at the skywalk collapse were citizens of Kansas City. The mental health community was ill-prepared for the demand for service it faced after the incident. One psychologist later noted that the victims represented the same race and class of the mental health community...white, middle class Americans. He is concerned that the mental health community and the surviving victims will fare even worse if the casualties and deaths are Black, Oriental, or Indian.

Since the Hyatt disaster, all uniformed police commanders and supervisors receive disaster training, one block of which deals with what they can do before, during and after an incident to reduce the chances of their personnel having post-incident problems.

A more recent incident occurred in Kansas City in November, 1988 which took the lives of six fire fighters. Following that incident, substantive changes have occurred in how the community deals with its rescue personnel in the aftermath of disasters. All fire service personnel receive training in critical incident stress and the fire department has been instrumental in the development of a metropolitan Kansas City Critical Incident Stress Debriefing Team.

## Recommendations

- 1 — Educate emergency service personnel (fire, police, and emergency medical service) in critical incident stress and provide them with stress reduction strategies before a major incident occurs.
- 2 — Train command and supervisory in the emergency services in what actions they can take to reduce the chances of post-incident problems in their personnel.
- 3 — Develop, train and operate teams of emergency service peers to be available to help emergency service personnel in the performance of their jobs.
- 4 — Identify individuals in the mental health community who are trained in critical incident stress and capable of providing advice and assistance in the event an incident occurs. Please note that this requires special training and merely obtaining the advice of a mental health person may not obtain the desired or needed results.
- 5 — Following an incident, implement critical incident stress reduction strategies, whether that be peer support, defusings, or mandatory attendance at critical incident stress debriefings.
- 6 — Encourage the development of a mental health community program that can be responsive to the needs of a wide range of ethnic and cultural groups in the community.

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# THE ROLE OF THE MINE EMERGENCY TECHNOLOGY TEAM

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Mine Safety and Health Administration  
Pittsburgh, Pennsylvania

The Mine Safety and Health Administration (MSHA) was established in the U. S. Department of labor by the Federal Mine Safety and Health Act of 1977. The 1977 Act authorizes MSHA to perform numerous safety and health related activities; some of the major activities are to develop and promulgate regulations, conduct inspections and investigations, approve equipment for use in mines, and approve plans submitted by mine operators. Approximately 3000 MSHA employees administer the requirements of the Act from four main organizational units with responsibilities for coal mines, metal and nonmetal mines, technical support and administration throughout the U. S. The MSHA has established 10 coal districts, 6 metal and nonmetal districts and 5 technical support centers. The MSHA's administration functions are handled primarily by the agency's headquarters in Arlington, Virginia.

When an accident occurs in a mine, the regulations require that the mine operator must immediately contact the nearest appropriate MSHA district office. If the accident is an emergency, such as an entrapment, inundation, explosion or fire, the district manager will collect all available information and then immediately dispatch personnel to the mine site. The district manager will then implement MSHA's notification plan, first notifying the appropriate administrator in the Arlington office. The administrator will then notify the Assistant Secretary of Labor for Mine Safety and Health, and provide regular updates of available information. The administrator will also notify the director of technical support. The administrator's office will also notify the director of technical support. The administrator's office and the technical support director's office will, in turn, notify necessary MSHA personnel, other government agencies, state agencies, miners representatives and other interested persons.

The technical support director's first notification will be to activate the Mine Emergency Technology Team (METT). The METT provides technical assistance to the senior MSHA official, usually the district manager, at a mine emergency site. This technical assistance aids the senior MSHA official to issue orders as he deems appropriate, to insure the safety of personnel in the mine and to approve plans to recover persons or any portion of the mine and return affected conditions to an acceptable state. Of course, the orders and plan approv-

als are performed with the knowledge and cooperation of the mine operator, the representative of the miners, state officials, and other interested parties. The technical assistance provided to the senior MSHA official by the METT is in addition to that which is available in the district.

The special equipment and expertise of the METT is centralized in MSHA's Technical Support. Particular emergency situations call for different combinations and degrees of the following capabilities:

- 1 — Logistic and procurement support;
- 2 — Seismic location of trapped miners from the surface, in conjunction with or in lieu of underground efforts;
- 3 — Large rescue-hole drilling capabilities;
- 4 — Establishment of surface and underground communication systems;
- 5 — Continual sampling and monitoring of mine gases at specified locations;
- 6 — Analyses of gas samples;
- 7 — Interpretation of gas sample results; and
- 8 — Probing of boreholes using two-way communication probes and TV probes.

The METT, directed by the chief, MSHA's Pittsburgh Health Technology Center (PHTC), includes personnel from the center's Mine Emergency Operations, Ventilation Division, and Toxic Materials Division. In addition to their METT responsibilities, the team members have regular duties in their areas of expertise. However, when an emergency occurs, emergency activities are given top priority.

## MINE EMERGENCY OPERATIONS

The Mine Emergency Operations (MEO) provides the METT with logistic and communication support, seismic location capabilities, borehole probing and the large rescue-hole drilling capabilities. The MEO is located in Hopeville, PA, approximately 30 miles north of Pittsburgh, and is included in references to the term "Pittsburgh Station." The MEO chief, who is an electronic engineer, directs contract personnel from Westinghouse Electric Corporation, and Rowan Drilling Company.

Westinghouse supplies three engineers and three technicians to the MEO activities in Pittsburgh on a day-

to-day basis, during which time they regularly operate, maintain, repair, improve and test the seismic and communications equipment. Westinghouse also supplies two engineers and one technician located in Baltimore, MD, to manage and provide the logistic support for the MEO program. This contractual arrangement has proven beneficial because it provides up to 20 additional technical specialists from the Westinghouse command post once the personnel from Pittsburgh have been dispatched to the mine emergency site.

Rowan Drilling Company supplies one drilling supervisor to the MEO activities in Pittsburgh on a day-to-day basis, during which time he regularly operates, maintains, repairs and improves the large hole drilling equipment. One engineer located in Houston, Texas, manages the program, and Rowan can provide up to 30 additional drilling specialists from various U. S. operations for emergency availability.

### **VENTILATION DIVISION**

The Ventilation Division provides expertise to the METT in gas and airflow sampling techniques and in the interpretation of the results of gas sample analysis. The division maintains and operates instrumentation for continuous sampling and recording of mine gases, such as methane, ethane, carbon monoxide and oxygen. The division chief, who is a mining engineer, serves as the supervisor of the METT at the emergency site. He directs 14 mining engineers and three technicians who are knowledgeable in entire mine and face ventilation systems, mine gas sampling and monitoring equipment. The Ventilation Division maintains computer models developed by the division and researchers from the Bureau of Mines, to assist in interpretation of gas sampling results with mine ventilation conditions. Also, new sampling equipment developed by the Bureau of Mines is tested side by side with the standard sampling equipment to determine its applicability to assessing underground conditions.

### **TOXIC MATERIALS DIVISION**

The Toxic Materials Division provides the METT with analytical capabilities for determining concentrations of methane, ethane, propane, acetylene, hydrogen, oxygen, carbon monoxide and nitrogen. Analyses are performed using two gas chromatographs that, in an emergency, are placed in a van in Pittsburgh and the van is then driven or flown to a mine site. The division chief, a chemist, directs one chemical engineer, two chemists, and two technicians, all of who are proficient in operating the gas chromatographs. The gas chromatographs are maintained in the laboratories in Pittsburgh and kept

operational. Upon emergency notification, the gas chromatographs are disconnected, packaged and placed in the van for transportation within a matter of hours. The Toxic Materials Division also conducts basic research on the development of analytical equipment to improve the quality, quantity and speed of gas analyses.

## **EMERGENCY RESPONSE LEVELS**

### **A. First Level Response**

The role of METT can best be described by dividing the emergency response into three levels. During the first response level, which is standby, the METT begins preparing the equipment and vehicles for travel and this normally takes from 2 to 3 hours. There have been over 40 first level responses in the last three years.

If the emergency occurs during regular work hours at the Pittsburgh Station, the team stops all other work, and preparation begins immediately. If the emergency occurs during off-work hours, members of the METT are contracted at their residences and, upon notification, proceed to the Pittsburgh Station to begin equipment and travel preparations.

With the team in standby preparations at the Pittsburgh Station, other first level response activities are in progress. The Westinghouse operations center in Baltimore, MD, checks on the availability and schedules of commercial, charter and Air Force aircraft. The center's staff also reviews locations and inventories of vendors for such items as probe-hole drilling equipment and supplies, for which they keep a semi-annually updated list.

The director of the Pittsburgh Research Center of the Bureau of Mines, is also notified and provided information. Potential equipment, services and personnel needs are discussed.

### **B. Second Level Response**

During the second response level, which is deployment, the METT is dispatched from the Pittsburgh Station to the mine emergency site. The communication van, gas analysis van, supply trailer, seismic system truck and Ventilation Division van are deployed by road or air, whichever is appropriate.

Upon arrival at the mine emergency site, the Ventilation and MEO chiefs will contact the senior MSHA official on site to be briefed and make arrangements for deployment of vehicles and equipment. In most instances, the chiefs travel by aircraft ahead of the rest of the team, and when they arrive, there is minimum delay in getting into operation. During discussions with the senior MSHA official, an action plan is developed for the METT. Since

the METT activities are primarily surface activities, the senior MSHA official and the chiefs develop the action plan in coordination with any underground activities and with the knowledge of the mine operator, representatives of the miners, state officials and other interested parties.

Since the team has been established, they have had 20 second level responses, some of which involved only part of the full team. Twelve of these responses have been required since October 1981. During the 1981-82 winter, three second level responses occurred within a two week period.

### C. Third Level Response

During the third response level, which is deployment of the large rescue-hole drill equipment, the METT is already on site and trapped miners cannot be reached by underground rescue activities. They have been located and are in communication via a small diameter probe hole.

The drill rig is then set up near the probe hole and proceeds to drill a large hole to rescue the miners. The

use of the large hole drill rig occurs several days after the first notification of a mine emergency. The drill rig has been deployed twice since it was built in 1970 and has never been used in the rescue of a trapped miner.

### METT ACTIVITIES DURING TWO MINE EMERGENCIES

Two mine emergencies that required a second level response illustrate the role of the METT. The first example is Mine A, which illustrates an underground sealing operation. The second example is the sealing and subsequent reopening of Mine B following an underground mine fire. In addition to its role during the emergency at Mine B, the METT also provided technical assistance necessary to reopen the mine. In both sealing and reopening procedures, the primary concern is the safety of persons either recovering the mine or rescuing trapped miners.

In November 1980, an underground explosion occurred at Mine A. When the METT arrived at the site, they were informed that the bodies of the five men killed in the explosion had been recovered; however, efforts to

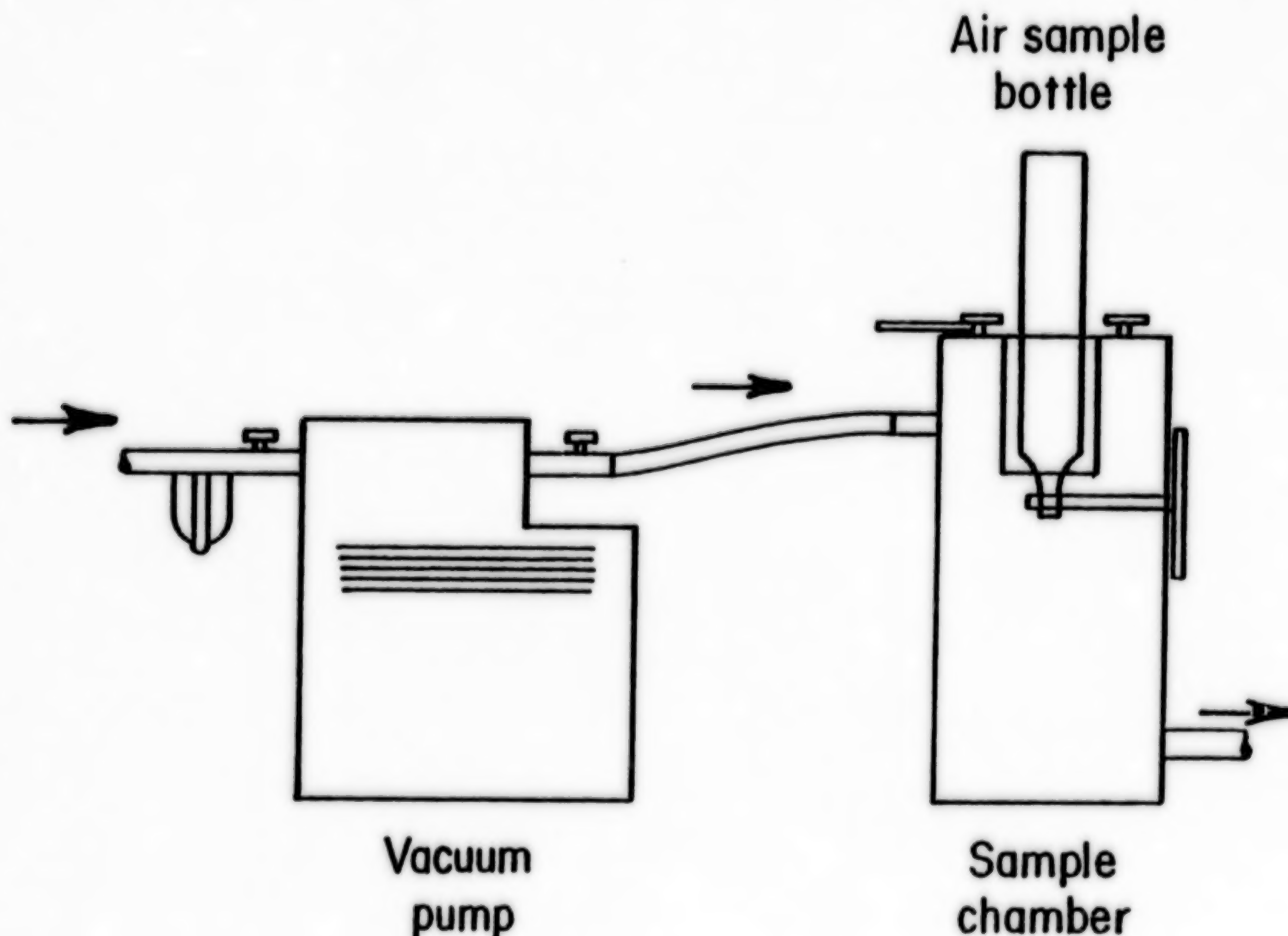


Figure 1. Schematic of air sampling train.

reventilate the area of the mine (2 South-1 East) where the explosion had occurred, had been unsuccessful.

Following the explosion and subsequent recovery operations at Mine A, the decision was made to seal the explosion area from the rest of the mine. A set of several seals were constructed across the 1 East entries to isolate the 2 South-1 East area from the remainder of the mine. During seal construction, a gas sampling line was placed in several seals so that samples of the atmosphere behind the seal could be collected.

Air samples are collected by pumping an air sample from behind the seal into an air sampling chamber. The sampling chamber is designed so that a vacuum bottle air sample can be taken without contaminating the sample. Figure 1 shows a schematic of the air sampling train.

The vacuum bottle is analyzed by chromatographic methods and interpreted by the METT. Interpretation of the sample consists primarily of an analysis of sample explosibility and trend analysis by graphing sample concentration versus time.

Figure 2 shows a daily plot of the explosibility based on effective combustible versus the effective inert as the gas mixture behind the Number 5 seal at Mine A passes through the explosive zone. The December 2 sample, which had a methane concentration of approximately 15%, was well out of the explosive zone because the effective inert was approximately 10%. Also, the gas mixtures following the December 2 sample fall in the "explosive when mixed with air" zone. The decay path that the gas mixture would take when mixed with air can

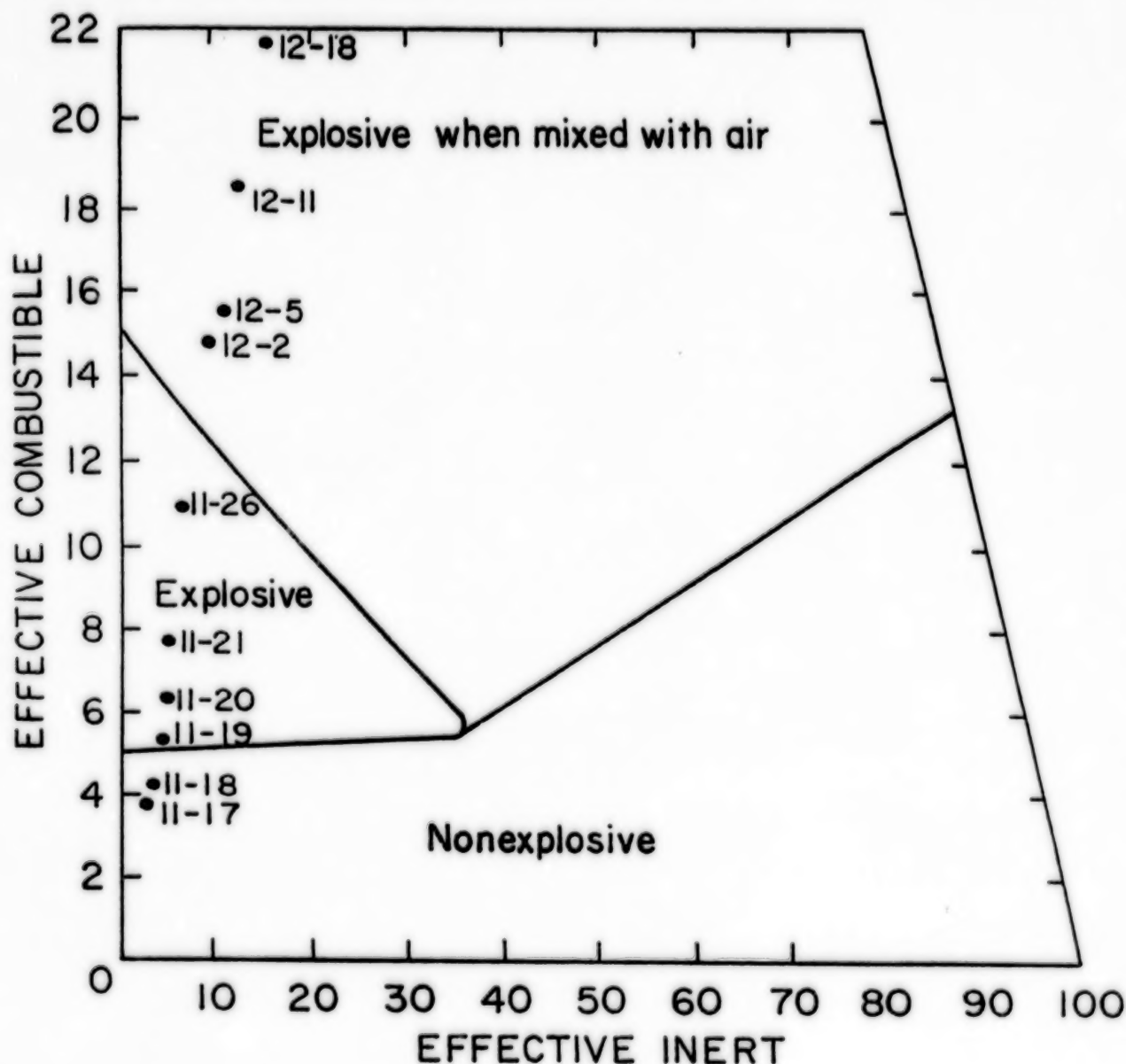


Figure 2. Plot of effective combustible versus effective inert for gas mixture in sealed area.

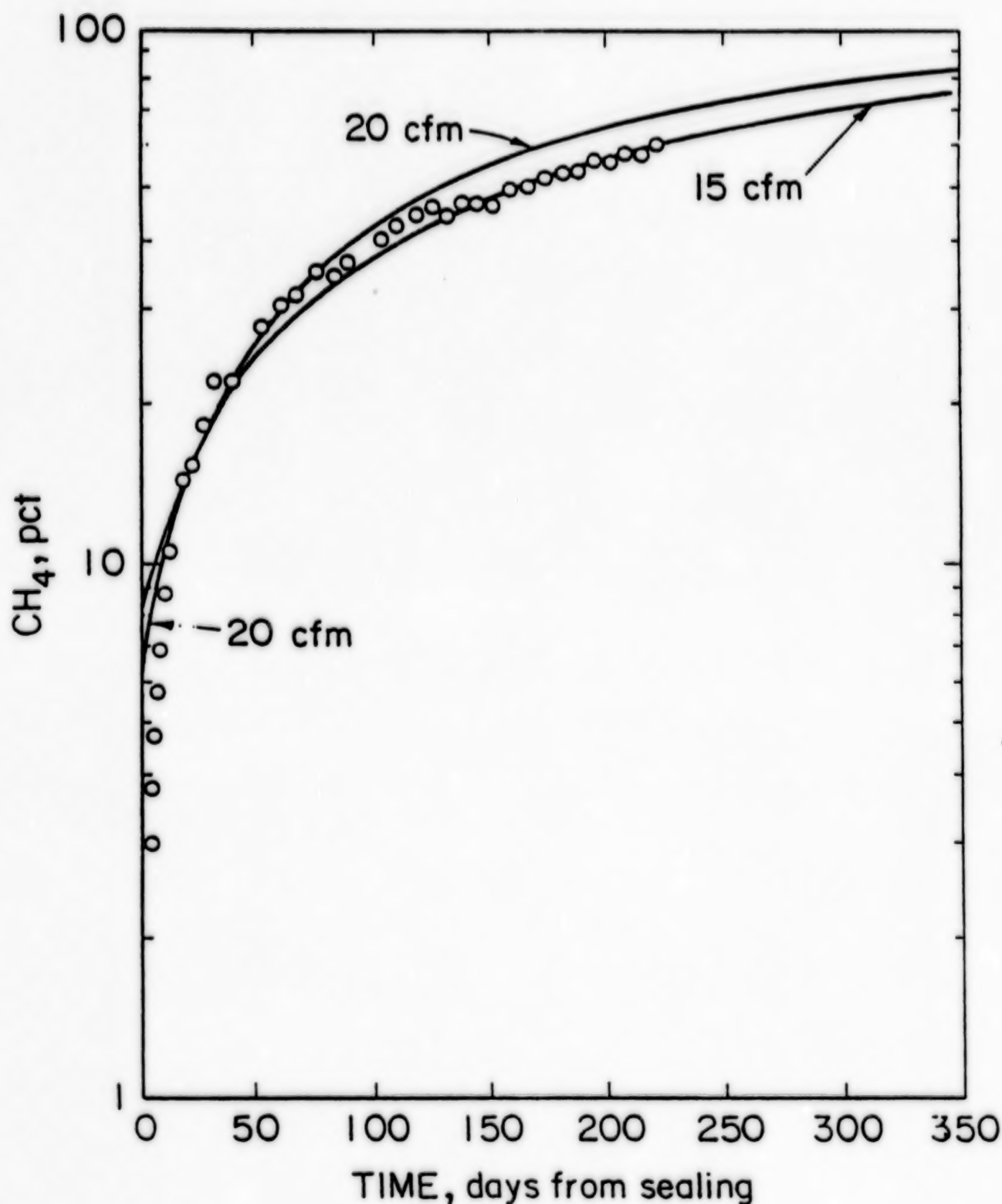


Figure 3. Plot of methane concentration versus time for gas concentration in sealed area.

be found by drawing a straight line between the gas mixture composition point and the origin of the graph.

Similarly, the path of the composition point when an inerting gas, such as nitrogen or carbon dioxide, is added to the gas mixture can be found by drawing a line

from the gas mixture composition point to the 0% combustible-100% inert point on the graph.

When the sealed volume is small, it may be possible to inject enough inert gas into the sealed area to move the gas mixture composition point into the non-

explosive zone. In any event, the addition of an inert gas to a sealed area moves the mixture composition down to the right. This would reduce the range through which the gas is explosive when the area behind the seal is reventilated.

Once the gas mixture within the sealed area passes through the explosive range, a plot is maintained of the

concentration of various gases versus time. Figure 3 shows the methane concentration within the sealed area as a function of time. Also shown on the graph are lines representing calculated methane concentrations bases on a 15 cubic feet per minute (CFM), and a 20 cfm methane liberation rate within the sealed area. The buildup of methane in a sealed area can be closely approximated by

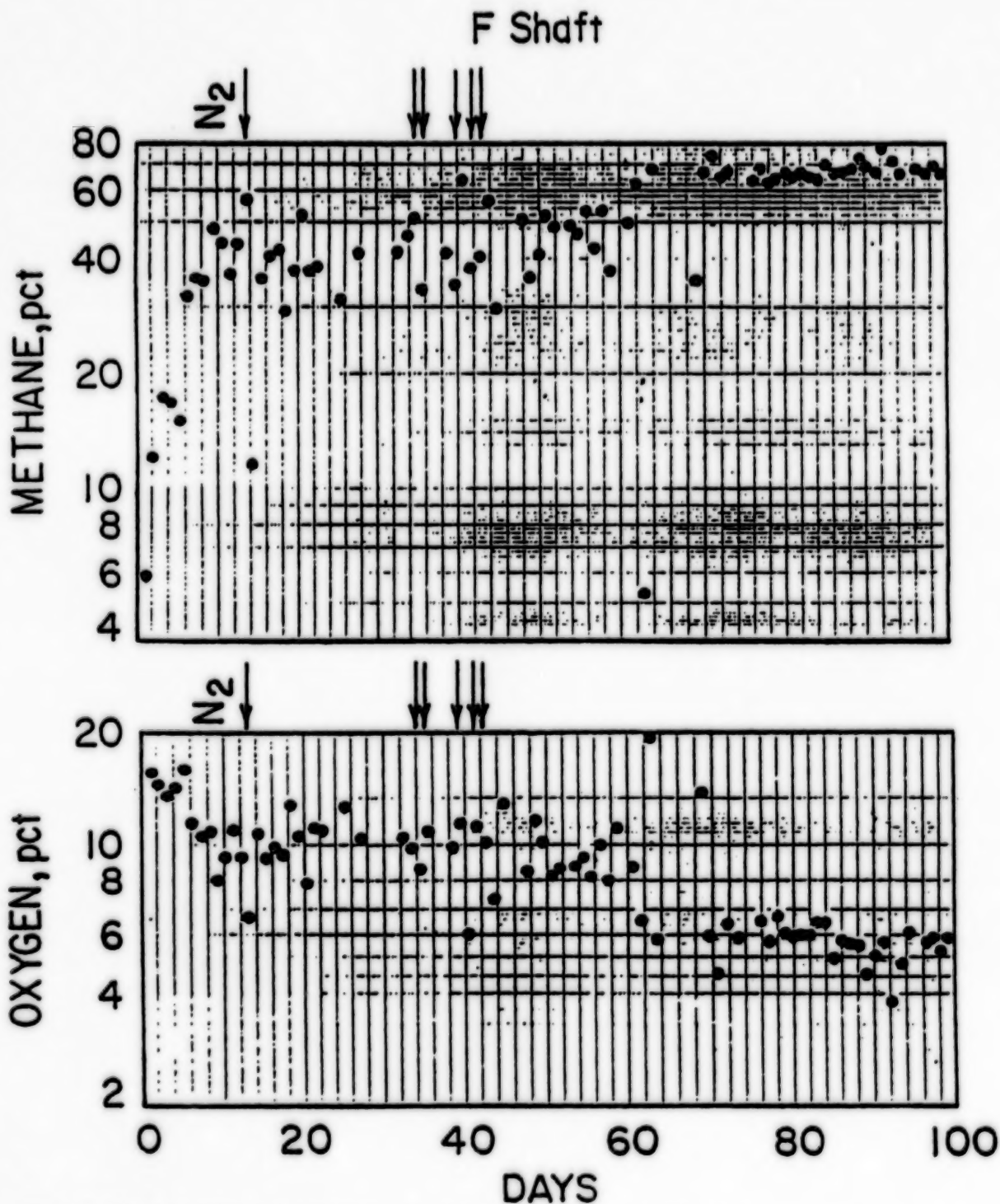


Figure 4. Plot of methane and oxygen concentration versus time for gas concentration in sealed mine.

mathematical models designed for that purpose.

This area in Mine A has remained sealed since the explosion. Air samples continue to be collected weekly, and they are evaluated by concentration versus time plots of methane and oxygen.

About one year later on November 25, 1981, an underground fire broke out at Mine B. The mine was accessed by six vertical shafts ranging in depth from 1000 to 1200 feet. All attempts to extinguish the fire underground were unsuccessful, and on November 26, 1982, the decision was made to seal the mine at the surface. The mine was sealed until March 6, 1982, when reopening procedures were started.

During sealing operations, air sample collection lines were placed in each of the shafts. An air sampling program was developed and Figures 4 and 5 show plots of gas concentration data that were maintained by the Ventilation Division personnel. The plots show the methane, oxygen and carbon monoxide concentrations at F Shaft during the period when the mine was sealed.

The arrows on the plot indicate where nitrogen was pumped into the fire area through vertical boreholes that had been drilled from the surface. Nitrogen was pumped into the fire area in an attempt to cool the fire. The air samples did not show any immediate effect of the injection of nitrogen. Since the fire had been extinguished by

F Shaft

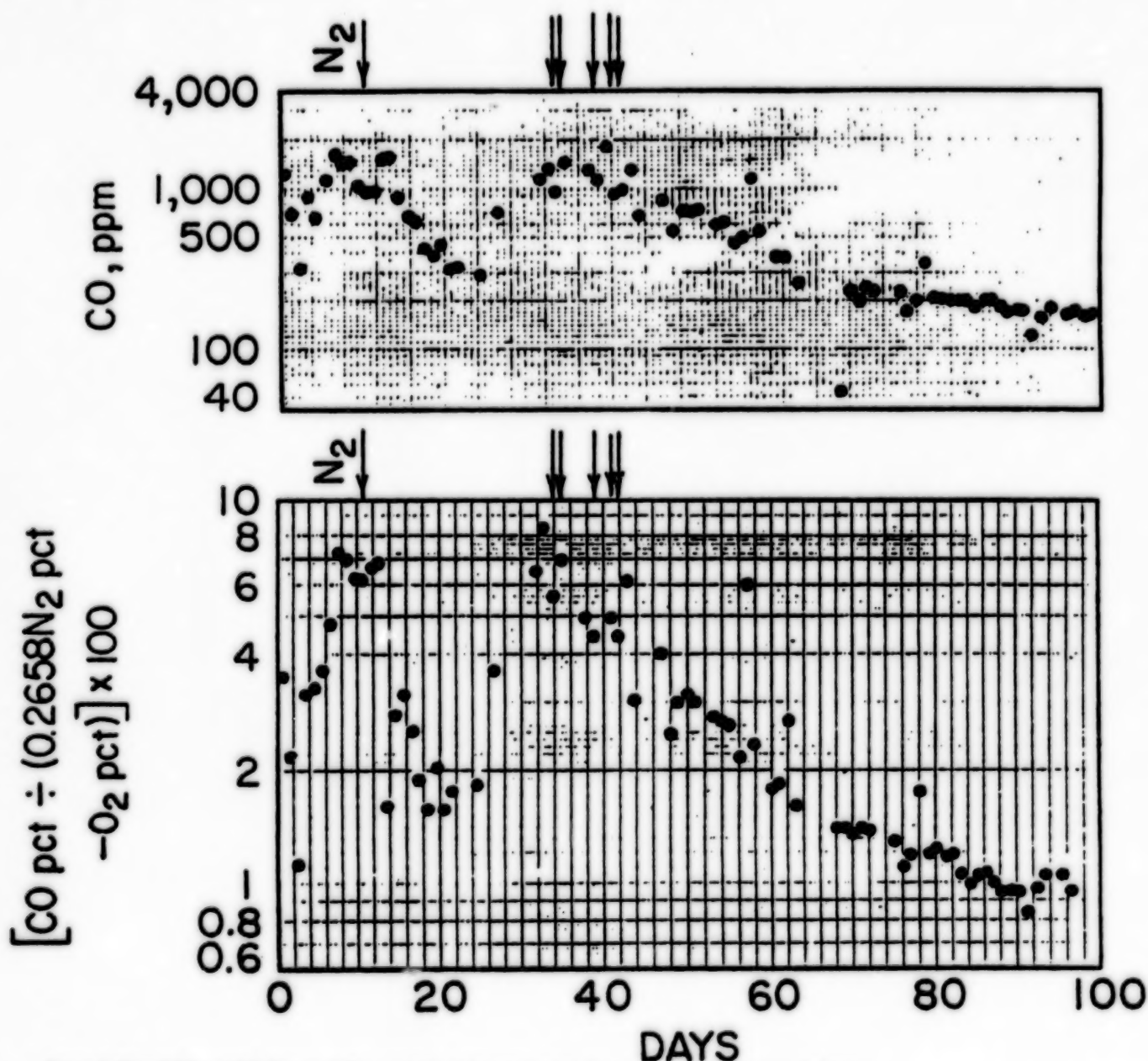


Figure 5. Plot of CO and CO-Oxygen deficiency ratio index versus time for gas concentrations in sealed mine.

the time the mine was reopened, the absolute effect of nitrogen injection into the fire area could not be determined.

Semi-logarithmic graph paper is used for the plots, so that gas concentrations covering several orders of magnitude can be plotted conveniently on the same graph. In general, as the methane concentration increased, the oxygen concentration decreased. The carbon monoxide concentration decreased due to absorption by the coal bed, indicating a decline in the progress of the fire. Also shown is a plot of the carbon monoxide deficiency ratio index versus time. The trend of this index appears to be a more sensitive indicator of the state of a fire than the absolute value of the carbon monoxide concentration.

The decision was made to reopen the mine after it had been sealed for 100 days. This decision was based primarily on experience at other mine fires in the area. Analysis of the gas samples did not indicate anything to adversely affect this decision.

During the reopening activities at Mine B, the METT monitored gas concentrations at shafts and fans in use during the various phases of the operations. This was accomplished by pumping samples from the various shafts or fans to a sampling station. Using non-dispersive infrared or electrochemical instrumentation, the METT was able to monitor the exhaust gases from the

mine continuously for carbon monoxide, carbon dioxide, methane and oxygen.

Over the four day period that it took to purge the methane from the mine, the METT continued their work. Various areas of the mine were ventilated by using the intake and return shafts in different combinations. The final intake and return shaft combination returned the mine ventilation system to its original configuration. After the mine rescue team explored the fire area and determined that the fire was out, METT removed the monitoring equipment from the shafts.

## SUMMARY

Under mine emergency conditions, the confusion that develops can often be a detriment to the rescue and recovery operations. The technical expertise and experience of the Mine Emergency Team in dealing with the various situations and alternatives that arise during a mine emergency lend to the successful completion of the job without sacrificing the safety of those individuals performing rescue and recovery work. The analytical and technical ability of the METT assists the responsible officials in recognizing and correcting potential hazards before they get out of control, thus benefiting the entire mine emergency operation.

# FORENSIC SCIENCE LABORATORY ROLE IN MASS DISASTER INVESTIGATION THE MIANUS RIVER BRIDGE COLLAPSE

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A bridge is a structure surmounting an obstacle such as a river, declivity, road, or railway and used as a passageway for pedestrian, motor vehicle, rail or other types of traffic. Man has been using bridges since very early in 3000 B.C. Throughout centuries of bridge building, man has developed a variety of bridge types for different needs or conditions. Today, there are approximately two million bridges around the world. Any man-made structure is subject to deterioration and failure, and bridges are no exception. A search of United Press International and Washington Post literature files for the period 1983-1990 revealed 90 citations concerning bridge collapse incidents.

Although a bridge collapse is a rare event, it is oftentimes a catastrophic event when it does occur. Since bridge collapses rarely occur, few state and local governments have the experience to handle such an incident. In addition, most of the emergency plans developed by state or local authorities for mass disaster or civil disorder do not include any plans to deal with bridge collapses. Bridge collapses always create mass confusion, traffic problems and difficulties in investigation. The tragedy, pain and anger often have longer and farther reaching effects than any other types of mass disasters. In 1983, a 100-foot section of the Mianus River bridge in southwestern Connecticut collapsed, wrecking 2,000 tons of steel and concrete and four vehicles. Three individuals lost their lives and three others were severely injured. Major traffic problems disrupted and inconvenienced millions of motorists and residents for almost a year. More than a thousand other accidents occurred as a result of the Mianus River bridge incident. The investigation of the bridge collapse created a special challenge for the forensic science laboratory. Through the challenge, important lessons were learned in the course of the investigation. This paper will focus on the forensic science laboratory's role in major disaster investigation.

## CASE HISTORY AND THE INITIAL RESPONSE

Because it is located between the cities of New York and Boston, Connecticut lies in a main transportation corridor. Interstate highway 95 is one of the major arteries connecting New York and New Jersey to the rest of the New England states. The Mianus River bridge is located in Greenwich, Connecticut, and it is the first bridge on I-95 after crossing the New York-Connecticut state line. The bridge is 2,656 feet long. It was designed by Tippetts-Abbett-McCarthy-Stratton of New York City in 1955 and built soon afterwards. The Mianus River bridge is typical of the so-called hung-span bridges that were built in Connecticut and elsewhere in the country in the 1950s.

On June 28, 1983 at 1:30 a.m., a 100-foot-long section of the Connecticut Turnpike (I-95) fell into the Mianus River in Greenwich, Connecticut, plunging four vehicles into the muddy water 70 feet below and



Figure 1. View of the accident scene of the Mianus River Bridge.

taking three lives. Three other people were seriously injured. They were dragged from the shallow water after the explosive sound of the bridge's collapse woke nearby residents. The critical incident log from the Connecticut State Police Troop G midnight shift showing the initial actions taken after the bridge collapsed appears in Table 1.

The Connecticut State Police were able to control the emergency situation by 5:00 a.m.. Troopers were assigned and road blocks were set up to prevent further accidents. Rescue and recovery operations were initiated. All the appropriate agencies had been notified. The response to the Mianus River Bridge collapse emergency was carried out in a speedy and proper fashion. Two scenes of the accident scene are illustrated in Figures 1 and 2.

### SCENE MANAGEMENT AND CONTINUED INVESTIGATION

After the initial emergency was over, the collapse of the Mianus River Bridge had created a major catastrophe for the State of Connecticut. The major traffic problem for motorists had to be resolved. An estimated 90,000 vehicles that normally used the Mianus River Bridge every day had to be rerouted. Large crowds and traffic had to be controlled to prevent other accidents, the loss of evidence and the security of the scene. The cause of the bridge failure had to be investigated. The sequence of events had to be determined and an effort made to reconstruct the accident. The following are some of the major tasks which were identified after the initial emergency response to the collapse of the Mianus River Bridge:

- 1 — Reroute the I-95 traffic.
- 2 — Traffic and crowd control.
- 3 — Security of scene.



Figure 2. View of the accident scene of the Mianus River Bridge.

- 4 — Set up communications center.
- 5 — Public information and new release.
- 6 — Logistic support.
- 7 — Identification of victims.
- 8 — Removal of the wreckage and debris.
- 9 — Collection and preservation of evidence.
- 10 — Interview witnesses and conduct investigation.
- 11 — Failure cause determination.
- 12 — Reconstruct the events.

Following the Mianus Bridge collapse, the Connecticut State Police instituted the following measures to carry out the above-mentioned tasks:

- 1 — Manpower allocation — forty additional troopers were assigned to bridge detail per day at the bridge site. Seven supervisors were assigned on a permanent basis to oversee the operation. All on and off ramps between exits 4 and 5 on

**Table 1. CRITICAL INCIDENT LOG FROM THE CONNECTICUT STATE POLICE TROOP G MIDNIGHT SHIFT**

Time	Incident and Action Taken	Time	Incident and Action Taken
0130	FATAL ACCIDENT — 3 deceased, Partial collapse of all eastbound lanes on Mianus River Bridge, on Rte. I-95. Two cars/two trucks fall through damaged area into the river.	0206	Major crime unit notified.
0135	HQ and Troop Command advised.	0221	Diver unable to enter water because of possible live wires. 2nd call for DOT light crew.
0137	57 PD confirms damage & reports possible vehicle in water.	0245	HQ notified chief ME, who advises Greenwich ME be contacted.
0139	DOT supervisors contacted.	0259	Connecticut Light & Power advised, and requested to scene.
0144	HQ to contact PIO.	0315	Gas company advised of situation.
0148	DOT electrical crew contacted for assistance.	0340	Consumer Protection notified of perishables on board one of the trucks.
0155	57 PD advises sending their divers to scene.	0355	Electrical power cutoff on both east and west bounds of bridge area.
0157	Troop A advises assigning 3 troopers to assist at the scene.	0400	Divers enter water to begin recovery operation.
0158	Emergency Service advises all Dept. divers are enroute to scene, along with a boat and lighting vehicle.		

east and west bound lanes of I-95 were closed. Traffic was rerouted via Route 1 through local towns and cities. Local police departments were contacted and participated in rerouting and traffic management. Due to the large amount of traffic both day and night for a long period of time, this effort caused considerable constraints on manpower. The rerouting also resulted in great inconvenience to motorists as well as to Greenwich residents. 40,000 enforcement summonses were issued for violations in the effort to maintain traffic flow. Over 1000 traffic accidents (including several fatalities), assaults and shootings were investigated in relation to the bridge collapse incident. Additionally, a truck squad was assigned to the Greenwich toll plaza to enforce weight regulations and avoid further tragedies on the local roadways. A temporary bridge was constructed at a cost of \$500,000 to relieve traffic pressure until more permanent repairs could be effected at the Mianus bridge site.

- 2 — A command post was set up on the Mianus bridge site to coordinate traffic enforcement and bridge collapse investigation. A public information officer was designated to coordinate the release of correct information about rerouting, travel advisories, and to deal with the significant media coverage.
- 3 — A special team, whose members included State Police and Department of Transportation personnel, was established to remove wreckage from the collapse site and to transport it to a central location for reassembly to facilitate failure analysis and cause study. A special clean-up effort was instituted to avoid spoilage and contamination of the cargo from the involved tractor-trailer.
- 4 — A special investigation team was assigned to coordinate the identification of victims, collection and security of victims' belongings, collection and preservation of physical evidence, interview of witnesses, and accident reconstruction and cause determination.

Throughout the investigation the following agencies were contacted for their assistance:

Local Police Departments  
Local Fire Departments

Office of Civil Preparedness  
Department of Transportation  
Department of Public Works  
Federal Bureau of Investigation  
National Transportation Safety Board  
Connecticut National Guard  
Department of Consumer Protection  
Chief Medical Examiner's Office

## FORENSIC INVESTIGATION AND ANALYSIS

The Connecticut State Police Forensic Laboratory was called upon to assist in the investigation of the collapse and aid in the reconstruction of the event.

The following tasks were identified during the investigation:

- 1 — Identification of victims.
- 2 — Identification of drivers.
- 3 — Identification of vehicles.
- 4 — Recognition and Recovery of Physical Evidence.
- 5 — Traffic Accident Reconstruction.
- 6 — Forensic Cause Determination.
- 7 — Maintenance of Evidence Integrity

### Identification of Victims

Bridge collapse victim identification is often complicated by a delay in the recovery of bodies due to river currents. In some instances, several months pass before victims are recovered miles downstream from the collapse site. In such a situation, victim identification offers a challenging problem. Table 2 illustrates several means of victim identification.

In this particular instance there were only three injured persons and three fatalities. The bodies of decedents and the injured persons were recovered soon after the accident. The injured were identified, treated, and

**Table 2. METHODS USED FOR VICTIM IDENTIFICATION.**

IDENTIFIERS	MEANS
Facial and feature recognition	Through relatives or friends
Identifications and papers	Through records
Fingerprints	Through fingerprint files
Dental x-rays	Through dental records
Race/Sex/Age/Height/Weight	Through medical records
Tattoos/Birth marks	Through relatives or friends
Hair/Eye color/Body features	Through relatives or friends
X-ray	Through medical records
Surgical markers	Through medical records
Blood grouping	Through medical records
Isoenzyme and DNA typing	Through blood, tissue, bone typing

released from Greenwich Hospital. The identification of those injured is straightforward. Identification of the deceased was greatly simplified by the availability of personal belongings and identifications. Relatives of the deceased were notified and made the identifications.

#### Identification of Drivers

In the course of a traffic accident investigation, the forensic laboratory is often requested to assist in the determination of driver when a vehicle has multiple occupants. Determination is made through the following means:

- 1 — Position of victims' bodies
- 2 — Imprint evidence on victim's body
- 3 — Type and degree of injury
- 4 — Locations of victim's fingerprints
- 5 — Location and distribution of blood, hair and tissue evidence in vehicle
- 6 — Location and distribution of other physical evidence
- 7 — Imprint evidence on the sole of victim's shoes
- 8 — Witnesses' statements

#### Identification of Vehicles

Four vehicles were found to have plunged 70 feet off the bridge and into the mussy waters below. Some parts were recovered, separated from the main parts of the vehicles.

The following vehicles were recovered and information related to the vehicles were reconstructed:

- 1 — 1983 Freightliner tractor, color white/blue, V.I.N. 1FUEYFYEDH215B24, Texas registration R12-287; 1977 Trailmobile refrigerated Box Trailer, Vehicle ID P62773. The vehicles were owned by K.L.M. Freight and were being

operated by Harold W. Bracy. Estimated gross weight 63,011 lbs.

- 2 — 1974 Mack Tractor, color beige, V.I.N. F747ST1492, Georgia Registration HK9717. Vehicle was owned by Fastway Transportation and had an estimated gross weight of 60,320 lbs.
- 3 — 1979 Toyota, 3 door sedan, color silver, V.I.N. MA 46-021519. Connecticut registration number WX 2107. Vehicle was owned by Elizabeth Weldon and was operated by Eileen Weldon. Estimated gross weight 3,005 lbs.
- 4 — 1981 BMW, 2 door coupe, color black, V.I.N. WBAAG3306B8014970, Connecticut registration number 333 ANA. Vehicle was owned and operated by Luis Zapata. Estimated gross weight 2,585 lbs.

Ownership and insurance companies were identified from vehicle registrations. The appropriate agencies were notified for insurance purposes.

#### Recognition and Recovery of Physical Evidence

Two types of physical evidence were present at the bridge collapse site; victims' belongings and material from the bridge. The former items must be collected, identified, inventoried, preserved, and finally released to the victims' families. The bridge wreckage must be properly recovered, collected, documented, and preserved for cause determination and reconstruction of sequence of events.

Table 3 shows one of the early evidence sheets used for assisting in the search for and recovery of bridge parts. Proper measures must be instituted to prevent loss of evidence due to souvenir hunters. A total of 450 items belonging to the six victims were identified, inventoried, and subsequently released to family members. Approximately 800 pieces of metal and other material from the

**Table 3. INVENTORY OF PARTS**

Mianus River Bridge, Greenwich, CT  
June 30, 1983  
Connecticut State Police  
Forensic Science Laboratory

(1) Parts Bridge Should Have:	(2) Parts Remaining on Bridge:	(3) Parts Recovered from Bridge Site	(4) Parts Missing
4 Hangers	1 Hanger	1 Hanger	2 Hangers
4 Pins	2 Pins	0 Pins	2 Pins
4 Bolts	1 Bolt	2 Bolts	1 Bolt
8 Nuts	1 Nut	2 Nuts	5 Nuts
8 Retainers (Caps)	1 Retainer (Cap)	4 Retainers (Caps)	3 Retainers (Caps)
8 4" OD Washers (1/4")	1 4" OD Washer (1/4")	1 4" OD Washer (1/4")	6 4" OD Washers (1/4")
8 2-1/2" OD Washers (1/8")	1 2-1/2" OD Washer (1/8")	2 2-1/2" OD Washers (1/8")	5 2-1/2" OD Washers (1/8")
16 14" OD Washers (1/4")	2 14" OD Washers (1/4")	0 14" OD Washers (1/4")	14 14" OD Washers (1/4")

bridge were collected and removed. Figures 3 and 4 show the recovery and collection operation. These materials were initially stored at the forensic laboratory and subsequently transported to a central location for failure study.

### **Traffic Accident Reconstruction**

During the investigation, several inconsistencies were apparent from witnesses' statements regarding the sequence of events, vehicle location and lane of travel. Using the physical evidence recovered from the bridge, tire marks on the road surface, recovered vehicle tires, and positions of the vehicles in the wreckage, the sequence of the accident was determined and the event was correctly reconstructed. Following are the results of the reconstruction:

- 1 — The 1973 Freightliner was operated by Bracy and approached the involved bridge deck in the right lane at a forward velocity of 48.0 – 59.5 mph.
- 2 — The 1974 Mack Tractor was operated by Pace and approached the involved bridge in the left lane at a forward velocity of 41.6 – 48.5 mph.
- 3 — The 1979 Toyota Sedan was operated by Weldon and approached the involved bridge in the center lane at a forward velocity of 31.6 – 37.6 mph.
- 4 — The 1981 BMW Sedan was operated by Zapata and approached the involved bridge in the left lane at a forward velocity of 33.9 – 52.8 mph.

### **Forensic Cause Determination**

The Mianus River Bridge collapse involved a sudden depression of the bridge deck and subsequent separation of a portion of the deck from its attachment points.



Figure 3. View of the recovery operation at the Mianus River Bridge.

The separation allowed the span to drop into the Mianus River. At approximately the time of the separation, several motor vehicles were either upon or closely approaching the involved structure assembly. During or shortly after the deck separation, some of those vehicles were driven off the elevated bridge structure into the river below. The resultant collisions produced fatal injuries to the occupants and massive damage to the involved vehicles. The forensic cause of the Mianus River Bridge collapse accident involved the following two separate types of determinations.

### **Vehicle accident cause determination**

There were no defects identified as causative factors, with respect to the pre-impact mechanical condition of the involved vehicles. Considering the estimated velocity of the involved vehicles and the highway I-95 geometry at the Mianus River Bridge, it is improbable that evasive maneuvers could have been taken which would have precluded the vault motion of these vehicles from the falling bridge deck.

### **Bridge failure determination**

The major reasons leading to the bridge collapse were:

- 1 — Oscillations caused by excessive vibrations; there are several factors that can cause bridge oscillations and create excessive vibrations.
  - A — Natural turbulence or gusts
  - B — The eddies created by solid cross section and shed from the structure
  - C — Undesirable aerodynamic actions
  - D — Other causes of violent vibrations
- 2 — Weakening of foundation or supports; the foundations or supports of the bridge



Figure 4. View of the recovery operation at the Mianus River Bridge.

could have been weakened for the following reasons:

- A — Metal fatigue
- B — Temperature differential changes
- C — Design errors
- D — Improper maintenance leading to excessive corrosion and deterioration

After the Mianus River Bridge collapse, one of the major focuses of investigation centered on whether the hang-over design of the bridge was inadequate. Metal parts which were suspected as defective were removed and transported to the State Police Forensic Science Laboratory for documentation and study. Figures 5 through 8 show pieces of deformed metal parts collected from the wreckage. Preliminary studies were conducted and then, due to the nature and complexity of analysis, the state contracted with Lehigh University's Material Science Department, Fritz Engineering Laboratory to examine the metal for failure. The specimens in Table 4 were tested.

#### Maintenance of Evidence Integrity

The collapse of the Mianus River Bridge received widespread media coverage. The media was constantly seeking information and photographs of recovered materials. Additionally, legal representatives of the victims, insurance companies, engineering firms, department of Transportation, National Highway Safety Board, and other federal, state, and local agencies has a common interest in obtaining and studying the material. The security of such evidence becomes a nightmare due to the limited available staff. An administrative decision was subsequently made to transport the evidence to a central location with state police personnel guarding the

**Table 4. SPECIMENS TESTED FOR METAL FAILURE.**

Exhibit Number	Description
4	Bridge hanger strap
5	Keeper plate
10	Bolt fragment
2	Crescent fracture from shoulder pin
13	Hanger strap
14	Hanger strap
23	Bridge wind lock
35	Wind lock tongue
37	Keeper plate with bolt and washers
53	Web extension and pin
54	Roller bearing
54-A	Sole plate for roller bearing
55	Sole plate
61	Web extension with pin, bolt, and plate
99	Bridge hanger
100	Bridge hanger
101	Pin cut from erect structure

material around the clock to prevent loss or damage. All of the physical evidence collected from the scene was properly documented at the time of recovery and after the forensic laboratory received it. An inventory sheet and chain of custody form were maintained throughout the investigation. Each time the evidence was viewed or examined by someone, the person's authorization was also checked and documented. The scientific and legal integrity of the evidence were thus maintained.

#### CONCLUSIONS

A bridge collapse is a catastrophic event. In recent history, several bridges in United States have collapsed: in 1967, collapse of the Silver Bridge over the Ohio

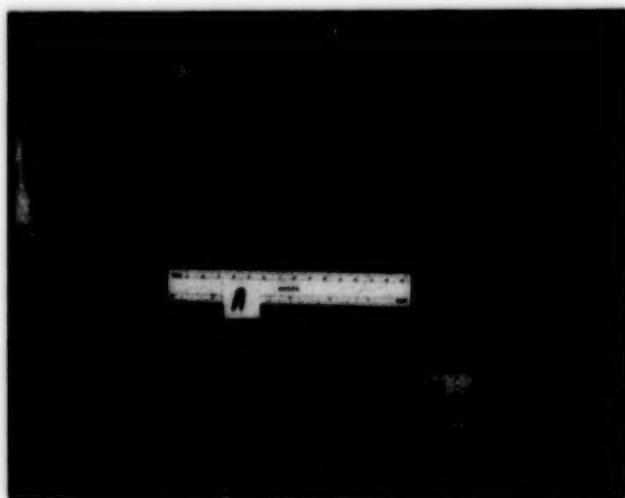


Figure 5. Physical evidence.

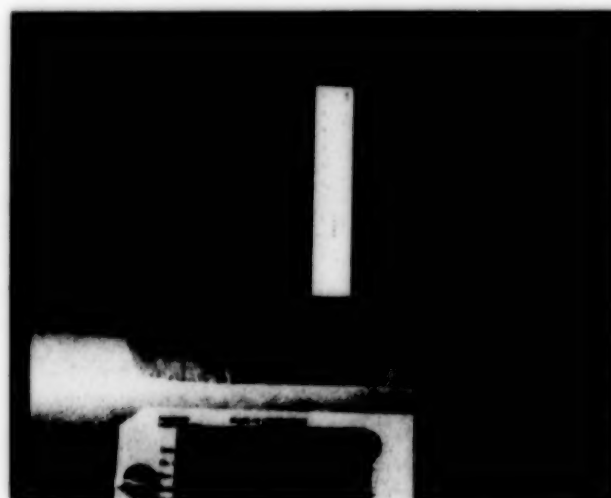


Figure 6. Physical evidence.

River at Point Pleasant, West Virginia, resulted in the loss of 46 lives; in 1987, another bridge over Schoharis Creek of the New York Thruway in New York State collapsed killing 10 persons; in 1989, the pillars of the Hatchis River Bridge in Tennessee gave away. Two 28-foot sections of the northbound Highway 51 bridge collapsed and killed at least seven people. A federal Highway Administration report indicated that 253,196 bridges, or 45 percent of the total 564,499 bridges that have been surveyed nationwide, were in serious need of work at the end of 1982. Of that total, 132,154 bridges were classified as structurally deficient, and 121,042 bridges were classified as functionally obsolete. Therefore, the deterioration of the highway system cannot be expressed too strongly. The potential for a major catastrophe from a bridge failure increases daily. There is not only an urgent need for the immediate rehabilitation of bridges, but an equally urgent need to develop emergency plans to handle the bridge collapse incidents.

After a year-long investigation, the National Transportation Safety Board concluded that the Mianus River Bridge collapse was the result of inadequate inspections and maintenance. A recent court ruling also indicated that inadequate maintenance by the state was respon-

sible for the incident, and a \$6 million out of court settlement was reached between the state and the victims' families.

Major disasters, both man-made and natural, are going to occur. The cost of such major disasters are high both financially and emotionally. Proper preparation for such disasters will ease the traumatic experience and enhance the subsequent investigation. The success of handling any major disaster and its follow-up investigation relies on the team approach among all the agencies involved. Forensic science laboratories, although they have traditionally played a minor role in major disaster investigations, can be of increasing importance and usefulness with the current emphasis on physical evidence and advances in forensic identification and analysis techniques.

#### ACKNOWLEDGEMENTS

We would like to thank the Connecticut State Police, Connecticut Department of Transportation, Western District Major Crime Squad, Lt. Col. John Mulligan, Dr. Wayne Lord, Dr. Lowell Levine, Kenneth Zercie, Sgt. Robert Mills, and the New York State Police for their assistance in this study.

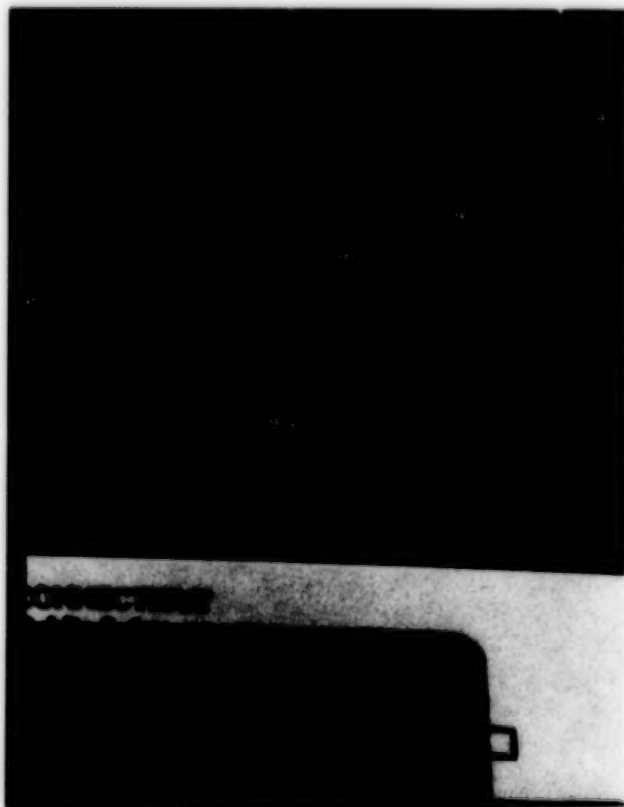


Figure 7. Physical evidence.



Figure 8. Physical evidence.

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# BOMBING OF AMERICAN ESTABLISHMENTS IN BEIRUT, LEBANON

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The mission of the Explosives Unit of the FBI Laboratory is to forensically examine materials recovered from bombing matters, to identify bomb components, reconstruct explosive and incendiary devices and compare them to items located in possession of subjects. Explosives Unit personnel are responsible for the on-site investigation at bombing crime scenes, searches and raids.

This paper concerns the three bombing attacks against American installations in Beirut, Lebanon during 1983 and 1984.

After the first attack against the American Embassy, the Washington Post Newspaper ran a cartoon indicating the first bombing was comparable to a nuclear bomb. Although meant as a joke, the devastation and magnitude of the terrorist bombings in Beirut, and those yet to come, were almost nuclear in size and proportion.

## ATTACK AGAINST THE AMERICAN EMBASSY

On April 18, 1983, the American Embassy came under the attack of a tremendous explosion. Through the official request of the U. S. Department of State, the Explosives Unit was directed to conduct a bombing crime scene investigation at this incident. The mission was to conduct the investigation in the same manner and guidelines as though it occurred in the U. S.

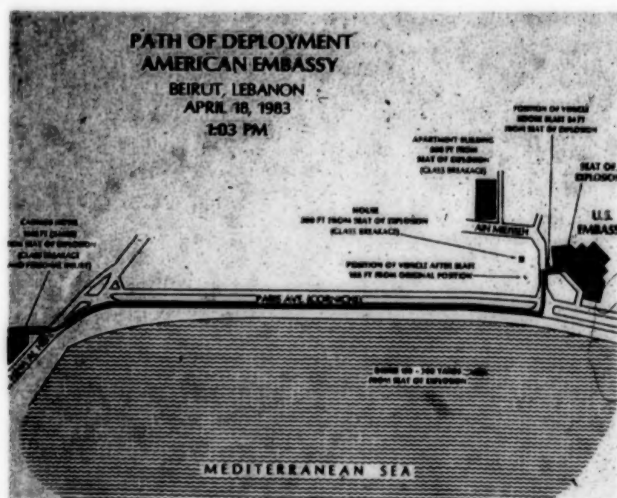


Figure 1. Schematic of location of American Embassy, Beirut, Lebanon, and the path of car bomb in the approach to the embassy.

The American Embassy was located in West Beirut, facing north, overlooking the Mediterranean Bay (Figure 1). The center rectangular structure was built in 1954 as a hotel. Four years later, two wings were added to this building. The wings were attached at the inner corners by double support columns. In its entirety, the building was an eight story structure with both a full basement and partial sub-basement (Figure 2).

The American news media made the statement at the time that the European style of construction was not as sound as the American style. Therefore, had this bomb been deployed at a building in the U. S., much less damage would have occurred. However, the opposite is actually true, because with the European style, the floor slabs are hooked around the support columns. With American building and construction techniques, knurled rebar is employed, thus, the cement ribs cling onto the rebar. Upon destruction and building fall, the European style slabs must first bow, bend, then finally break. In comparison, the American style floors will, upon tremendous weight, readily give way and total collapse will occur. Overall, this was a very well built structure. Also stated by the American media was that the bomb had been deployed through the entrance of the semi-circular drive-through. As reflected in the crime scene itself, the entrance portion of the portico which extended into the courtyard was still remaining, proving this statement false.

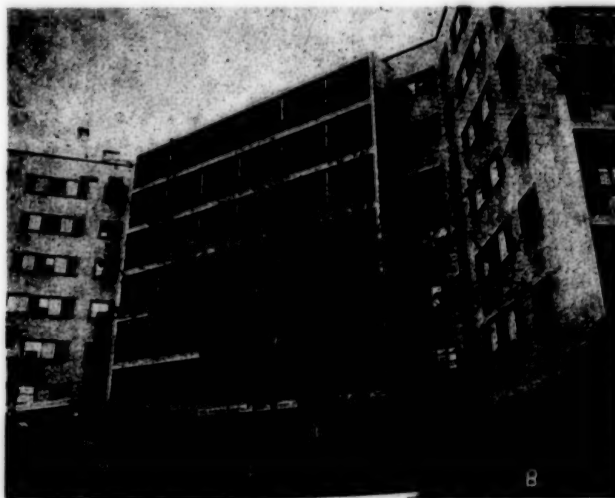


Figure 2. Exterior view of American Embassy, Beirut, Lebanon, prior to car bomb attack.

Seven separate fires occurred directly after the explosion. Lebanese fire fighters and equipment remained on scene after extinguishing the fires in order to assist with the recovery of victims.

A French military unit on duty, approximately 0.5 Km away, provided exceptional assistance to the U. S. Government by not only aiding the injured, but also in establishing a perimeter of security thus preventing classified items remaining in the Embassy from being pillaged.

There was a great problem in identifying the dead, as the explosion occurred in direct contact with the Embassy cafeteria. Only two individuals, who were sitting behind an inner pillar, survived. Some individuals were literally vaporized by the blast effects of the explosion.

The remaining Embassy structure (Figure 3) was rocking back and forth at approximately 2.5 cm per hour. A separate station was established for friends and loved ones awaiting word of victims. A survey of the remaining structure was taken every hour and closely scrutinized. Construction engineers on the scene were worried that the remaining portion of the Embassy would soon collapse.

Power and utilities were knocked out at 1:03 p.m., thus establishing the time of detonation.

Inside the entrance of the Embassy was a small foyer with steps leading up to the Marine Security Guard Post Number 1. Although the Lexguard (bullet proof

glass), protected the Marine Security Guard from fragmentation damage, the explosive forces drove the marine and Lexguard into the inner wall. The explosive main charge from the bomb was identified from examination of the soot and residue on the bullet proof glass as unconsumed particles of pentaerythritol tetranitrate (PETN).

A portion of the sixth floor of the remaining Embassy structure, directly above the point of detonation, remained. Vertical blast damage was tremendous. A portion of the doorjamb was located projected from the door opening into an opposite wall.

On the fifth floor, on the farthest point opposite the blast, window glass was drawn into two rooms by the negative pressure in bringing the atmosphere back to normal inside the building.

Seven of the eight floors above the crater had totally collapsed, as can be seen in Figure 3. Directly above on the eighth floor was the Ambassador's office. Ambassador Dillion was speaking on the telephone at the time of the blast when the 0.3 m concrete wall plunged on top of him.

For security reasons due, to previous threats and attacks on the Ambassador, when he was in the Embassy, his vehicle was parked allowing the back door to open directly at the front entrance. The lead vehicle for the Ambassador's convoy was a 1978 full-size Plymouth Fury parked in front of the Ambassador's car. The chase vehicle parked behind was a Chevrolet Suburban (rover-type vehicle). Separate crime scenes had to be conducted upon all three of these vehicles when Lebanese explosives experts claimed that each of the vehicles actually contained an explosive charge. Forensic evidence proved otherwise. The lead vehicle was parked approximately 7.5 m from the point of detonation.

A number of vehicles were parked along the side street on the northwest corner of the Embassy. One vehicle, approximately 28 m from the point of detonation, was picked up by the shock wave and propelled 26 m down into a ravine killing a small Lebanese girl.

The spalling effect from the propagation wave was noted as exterior damage on vehicles parked up to 68 m from point of detonation.

The Cadmos Hotel is located 0.5 Km from the point of detonation (distance noted in Figure 1). Most of the windows were shattered by the shock wave and an individual on the fifth floor was propelled into an inner wall breaking his femur bone.

Most of the engine block from the bomb-laden vehicle was recovered two floors up and two rooms into the Embassy structure from point of detonation. Vehicle parts recovered later lead to positive identification of this vehicle, enabling investigators to trace it back into Lebanon from the U. S.

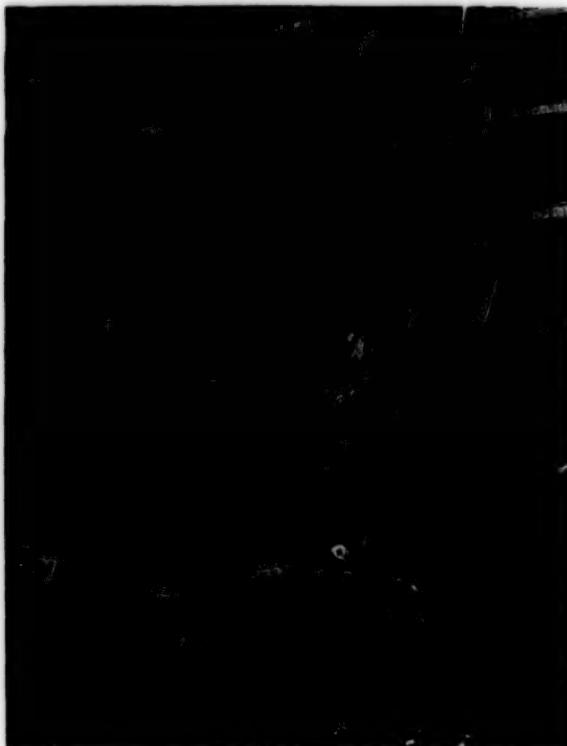


Figure 3. Exterior view of American Embassy, Beirut, Lebanon, after the car bomb attack.

A U. S. Navy Underwater Demolition Team was utilized to conduct a 140 m grid search into the Mediterranean Bay in front of the Embassy compound. Numerous pieces of evidence were recovered including parts of the bomb vehicle, the Embassy structure and body parts.

Approximately 900 Kg of items of evidence were recovered. Part of the truck was triangulated back to the crater in order to identify its exact position upon detonation. Portions of the back tire of the truck, for example, were recovered 46 cm into the two support columns (Figure 4). This provided the positive determination that the bomb-laden vehicle had penetrated the interior confines of the Embassy.

On-site, sifting screens were made. The waffle frames from the Embassy's lights were utilized in the sifting/screening operation as well as mosquito netting from Marine tents. Because these items were not sturdy, new screens had to be made approximately every 30 minutes.

A portion of a tibia bone, believed to have come from the sacrificial driver was recovered approximately 0.6 m inside the crater and was taken back to the FBI Laboratory for forensic analysis. A blood type was obtained from this piece of bone.

Extensive interviews were conducted of witnesses and Embassy officials which lead to recovering part of the canvas material employed to secrete the explosives in the bed of the bomb-laden truck. A small length of blasting cap leg wire was recovered for identification as well.

The crater was surveyed and determined to measure 4.5 m by 3 m in an oblong shape, due to the vehicle moving at the time of detonation. The depth of the crater measured 0.93 m through a 12.7 cm concrete slab.



Figure 4. Interview view of American Embassy, Beirut, Lebanon, after the car bomb attack. Note the damage done to the support columns.

The building and surrounding area was measured, charted and diagrammed so that a scientific estimate of the explosive charge weight could be stated. A conservative estimate was that over 900 Kg explosive equivalent was deployed in this attack. Further, gas storage vessels, foreign to the Embassy, were recovered which exhibited extreme explosive damage indicating them to have been in intimate contact with the explosive upon detonation. Through investigation and intelligence gathering we determined that a hydrocarbon fuel/gas was used in conjunction with the explosive main charge to enhance the explosive effects. To date, research and testing by the FBI Laboratory and a number of other renowned laboratories in the U. S. and Europe, have confirmed that this technique is possible. Ideally, it enhances the explosive effect and impulse time on target, furnishing a high yield/low energy explosive effect.

In its development, the bomb laden vehicle, a 680 Kg Chevrolet pick-up truck, entered the exit side of the driver-through and rammed itself into the security area of the Embassy detonating inside the building.

A sign was located over the entrance of the Marine Security Guard's private quarters. It reads "don't take life so seriously...you'll never get out of it alive". Eighty-nine people did not; 17 were Americans.

#### ATTACK AGAINST THE MARINE CORPS

The second bombing attack against an American installation was against the U. S. Marine Corps (USMC) 24th Marine Amphibious Unit (MAU) Battalion Landing Team (BLT) Headquarters building on October 23, 1982. The previous Embassy attack was, in comparison, only a firecracker.



Figure 5. Exterior view of U. S. Marine Corps (USMC) 24th Marine Amphibious Unit (MAU) Battalion Landing Team (BLT) Headquarters building.

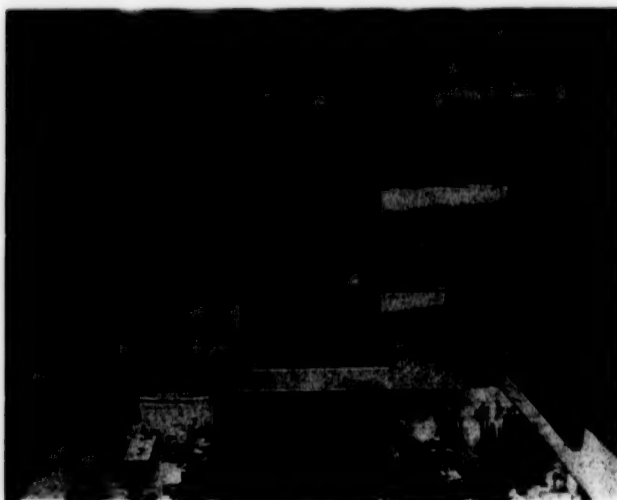


Figure 6. Interior view of the Marine Corps (USMC) 24th Marine Amphibious Unit (MAU) Battalion Landing Team (BLT) Headquarters building showing the atrium.

Almost instantaneously, the French military headquarters located approximately 8 Km away, came under a similar terrorist bombing attack.

The BLT Headquarters building was housed in the Beirut International Airport complex. This building was an extremely sound and well built structure, having nine support columns in the front and back, with four support columns on each side. Each column was actually four support columns joined together; each having 36 — 3.8 cm reinforcing bars comprising a total girth of 4.6 m of cement (Figure 5).

In the center of the building was an open atrium which extended from the ground floor up through the fourth floor and roof (Figure 6).

The aftermath from the bombing attack was like something never seen before by anyone within the military or law enforcement explosives community. The explosion literally raised the floors from the support columns, exfoliating them slightly, and thereafter pancaking then one on top of the other. Figure 7 depicts the results of the explosion.

Blast damage outside the building was tremendous. Windows were shattered out at the air traffic controller's tower, 500 m away, causing injury to individuals therein. The BLT building itself became fragmentation, propelling cement block and reinforcing over 200 m into occupied tents. Locked metal doors were ripped off backwards from metal doorjambes by the negative pressure effect over 340 m away.

Power and utilities were eliminated at 6:21 a.m., thus establishing the time of attack.

The crater measured 11.9 m by 9 m in an oblong shape.

An approximate 1.2 by 2.4 m piece of the foundation slab which was 17.8 cm of reinforced concrete with



Figure 7. Aerial view of the Marine Corps (USMC) 24th Marine Amphibious Unit (MAU) Battalion Landing Team (BLT) Headquarters building after the bombing.

a 2.5 cm marble facing was driven down into the seat of the crater 2.4 m. The crater, then, was 2.6 m in depth (Figure 8).

The BLT building had two basements with an inter-connecting hallway. The blast forces bowed the hallway wall at a 11.9 m arc, 1.5 m off the perpendicular.

Literally hundreds of fragments of reinforcement bars were located which had been ripped in two by explosive forces through a combination of compression and tension. Some pieces of reinforcement bar that were located could be snapped as if a rubber band (Figure 9).

At 6.1 m from point of detonation, trees were uprooted and their leaves shredded. Pieces of metal from metal lockers were found wrapped around a tree prior to having been uprooted (Figure 10).



Figure 8. Aerial view of the Marine Corps (USMC) 24th Marine Amphibious Unit (MAU) Battalion Landing Team (BLT) Headquarters building after the bombing. The bomb crater can be seen.



Figure 9. View of the wreckage of the BLT showing the reinforced bars bent.

Even at 114 m, evidence was located revealing metal from the building impinged onto stationary objects. The marine guard stationed in this area still had over 30% hearing loss when interviewed 11 days after the incident.

The nearest building was 78 m from the blast. All windows but two in this building were totally shattered. Walls in this building were shaken loose from the positive pressure effect and then bowed back 0.9 m by the negative pressure effect. Locked metal doors in this building at 108.5 m from point of detonation were ripped off their doorjamb.

Two Marines were never found. Through interviews, it was determined that these two Marines worked out every morning with an exercise machine which was located approximately 9.1 m from the point of detonation. Underwear recovered on part of the remaining building from that area had the residue from the explosive main charge identified again as unconsumed PETN.

A squad of Marines from the line infantry companies were trained on-site for assisting in the processing of the crime scene. They worked at the bombing site by day and protected us at night during the routine shelling and fire fights.

The bomb laden vehicle in the BLT attack was identified as a 17,214 Kg Mercedes stake bed truck.

Estimates from analysis of the crater destruction and the surrounding blast area determined that the bomb deployed against the BLT Headquarters contained over 5,443 Kg the explosive equivalent yield of TNT in this attack. Later analysis and information proved this estimate to be very conservative. Again, as in the prior American Embassy attack, gas storage vessels foreign to the scene were recovered during the processing of this crime scene. A total of 255 people died in this attack, 241 of them Marines.



Figure 10. Bar bent around a tree after explosion at BLT.

### ATTACK AGAINST THE AMERICAN EMBASSY ANNEX

On September 20, 1984, our American Embassy Annex located in East Beirut, Lebanon was the victim of yet another terrorist attack. The method of attack and path of deployment was almost identical to the other attacks (Figure 11). However, the explosive damage and type of evidence located at the scene was completely different.

Very little of the bomb laden vehicle was found. Small fragments of the engine block were recovered over a 0.8 Km away. During the vehicle's route of march, it careened off the dragon's teeth barriers and a guard shack, depositing paint. This paint was examined by instrumental methods to aid in the identification of the bomb vehicle as a late model American General Motors Corporation van.



Figure 11. Aerial view of American Embassy Annex, Beirut, Lebanon, showing approach of car bomb



Figure 12. Blast crater at American Embassy Annex.

A number of guards shot at this vehicle before it ended up exploding in the street almost at the center-front of the Annex after hitting one of three Embassy rover vehicles. The crater measured 5.4 m by 5 m in an oval shape having a depth of 1.6 m (Figure 12). As a point of fact, in this attack, no gas containment vessels were recovered. Explosive damage analysis estimated the explosive charge in this bombing at over 1,361 Kg the explosive equivalent yield of TNT.

Blast damage was tremendous (Figure 13). One of the Embassy vehicles parked 22 m from the point of detonation was turned over and set afire by the blast effects. Another Embassy vehicle parked 10.7 m from point of detonation was picked up by the explosive forces and hurled 12.2 m, wrapping the vehicle around a tree. At 82.9 m, in the side parking lot of the Embassy Annex, 16 vehicles and one bus had all of their rolled up windows shattered. It takes approximately 0.23 Kg per 6.4 square cm of pressure to break a standard car window.

A 3.6 m retaining wall was in front of the Annex structure which reflected most of the force of the explosion, saving the structure from major devastation. I-beams lying parallel to the blast next to this wall approximately 7.3 m from the crater were crushed by the explosive forces.



Figure 13. Blast damage at side of the building.

Time of detonation of this incident was about 11:45 a.m. The U. S. Ambassador was present with the British Ambassador at that time inside the Embassy on the fifth floor. The explosive utilized in this bombing was RDX (cyclotrimethylene trinitramine).

Ironically, terrorism continues. In the downing of a French UTA DC-10 plane in Chad in 1989, Ambassador Bob Pugh's wife, Linda, was onboard and killed. Ambassador and Mrs. Pugh survived the first Embassy bombings in Lebanon in 1983.

In 1986, primarily because of the Beirut bombing attacks, the U. S. enacted new extraterritorial jurisdiction laws which enabled the FBI to not only investigate these incidents, but charge the subjects in the U. S. for their terrorist acts. The United States Government presently has over nine warrants of arrest for these international terrorists involved in terrorist attacks against America.

# **PATHOLOGY OF TERRORISM A MEDICOLEGAL PERSPECTIVE**

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There is an enormous amount of interest in terrorism and counter-terrorism based on the multitude of papers, periodicals and books appearing on the newsstands. For a long time, terrorism was thought as of a form of guerilla warfare waged for economic reasons just as much as ideological. It is based on violence and fear, it targets people more so than states. It is a strategy or series of strategies designed to undermine society's foundations and in so doing bring about change.

Studies have shown the degree of organization necessary to wage an undeclared war against organizations whether they be political, economic or cultural. The victims are rarely random casualties but rather well-defined targets hit at a time of greater vulnerability. This seminar is presented with the purpose of exploring the role of forensics in the investigation and hopefully the timely apprehension of terrorists.

## **INTRODUCTION**

Who is at risk? What safeguards, if any, exist? Two relatively simple questions with rather long and complicated answers. Potentially, anyone is at risk, particularly if they are identified with a cause or condition. Many of the victims are victims because they are Americans or in the military. While most of the media attention is directed to terrorist activities overseas, there is a strong element within the United States whether they be dissidents or active advocates of civil disobedience. The bombings or abortion clinics are examples just as much as the activities of various Klan and Neo-Nazi organizations. In each of these situations, violence and fear are used to threaten and hold hostage opposing groups or organizations. It is probably the absence of fair-play that causes so much reaction. It is a reactionary response which the terrorist hopes to engender. A state's reactionary measures, particularly those which are internal, serve to further the goals of the terrorist. Since the rules of engagement are constantly changing, so to are the guidelines suggested for safeguarding your businesses, family and self.

## **PATHOLOGY OF TERRORISM**

From a forensic point of view, the injuries observed are rarely unusual. More often than not it is the numbers

or apparent indiscriminations that make such acts so abominable. Bombings are a frequent means of striking back at the system. They have profound effect both physically and psychologically. Beatings and executions are common place and are designed to serve notice as to who in fact is in control. This control or the desire to have such control appears to be a driving force in many cases of torture and psychological harassment. It is from the study of physical trauma resulting from acts of terrorism that we hope to understand and eventually combat the psychological or physiological effects of terrorism. The name of the game is reconstruction of the events leading up to the grand finale. If the reconstructions are faulty, so will be the proposed solutions. If the investigations are incomplete, so will be the profiling necessary to target such individuals. A far greater aspect of a death investigation than the cause of death is the manner of death. It is in our studying of the circumstances of death that we try to determine intent and in so doing, responsibility. Success in this endeavor requires multiple autopsies: postmortems of the victims, postmortems of the circumstances, and postmortems of the pre-existing conditions. For the most part, it is a one-shot opportunity. There is never a second chance to make a first impression. What is lost can rarely be regained. Since forensics revolves around the principle that whatever you do or wheresoever you go, you take a portion and leave a portion; the importance of trace evidence and criminalistics cannot be overstated. It is this pre-occupation with detail that makes the difference in the success or failure of the investigation. Needless to say, the investigation must be complete and well documented. Advances in technology will give us more information but that information will only be as good as the material collected and preserved. For the medicolegal death investigator, that means three things: identification, documentation, and correlation. We have mentioned these three parameters several times previously and do so again simply to emphasize the need for continuity and the return to basics. We must ask, as we always ask, six basic questions of the victim:

- 1 — Who are you?
- 2 — Where were you hurt?
- 3 — How were you injured?
- 4 — When were you injured?

5 — What injured you?

6 — If injured by another, by whom?

As investigators, we understand the importance of *modus operandi*. It is the *modus operandi* that provides the first clues of identity. We rely on repetition and the fallibility of man. It is these doctrines that persuade us to believe that there is no perfect crime and no perfect criminal. If that is so, a truth rather than a conviction, then no crime is unsolvable.

Terrorism is a universally recognized crime which is exploitative. It is theater, and can be played anywhere or everywhere! Action models include: execution, kidnapping, assaults, raids and penetrations, occupations, ambush and sabotage. It is a war of nerves. The victim is frequently characterized as: apparently wealthy, representing importance, valuable to someone, and accessible. The selection of the victim-target involves four phases:

- 1 — Potential targets, parameters defined.
- 2 — Selection of targets based on surveillance and a process of elimination.
- 3 — Risk analysis, selection of targets of opportunity.
- 4 — The plan rehearsed and evaluated for success and surprise.

"One man's terrorist is another man's freedom fighter". It is this simplistic ideal that underscores the basis for public opinion. What are the goals of the terrorist? Generally, these are divided into two categories: immediate and long-term. Immediate goals are designed to gain publicity and expose vulnerabilities. They are:

- obtain worldwide, national or local recognition for "the cause"
- force governments to over-react and create repression leading to public dissension
- expose a government's inability to protect its citizens
- obtain monies and equipment
- discourage impending investments or assistance programs

The areas of operation may be transnational (State supported), international (State controlled or directed), or national (domestic). The types of terrorists are usually defined by their motivation: political (ideological), religious fanatic, criminal (monetary), insane (personal, psychological disorders), or ordinary citizens (violent civil disobedience). The typical profile is that of a 22-24 year old, well educated, from the upper middle-class. Illyrich Ramez Sanches "Carlos the Jackal" is a Venezuelan from a wealthy family credited with a number of assassinations. He is perhaps the most notorious of the terrorists and was the title character in Frederick Forsythe's novel: *The Day of the Jackal*. There seems to be a shift from government targets to businesses; in 1985, 35% of

terrorist acts were directed towards businesses, particularly those which are international.

There are six basic tactics used by terrorists: bombings (50%), assassinations, armed assaults, kidnappings, hi-jacking and barricade and hostage situations. The goals and means for these are well known and are characterized in Carlos Marighella's book: *Mini-Manual for the Urban Guerilla*, which is widely available. A Rand Corporation study on kidnapping showed that these acts had a 100% probability of gaining publicity, an 87% probability of success, an 83% probability of safe passage if that was the sole demand, a 79% probability that the terrorists would escape punishment whether hostages were seized or not, a 69% probability that all or part of all demands beyond safe passage would be met, and a 67% probability of escape even without any obtained concessions through the underground, acceptance of safe passage, or surrendering to a sympathetic government.

Terrorism is a strategy of provocation. Success is only possible when the political conditions are ripe. The continuing civil struggle in Northern Ireland is such a case. Where terrorism has been successful, its goals were limited and well-defined. These are represented by multiple strikes where acts of terrorism were used to force industrial concessions. They have been successful, when part of a much wider strategy as was seen by the killing of village elders by the Vietcong in the 1950s in preparation for a take-over from within.

The dagger and pistol were the traditional weapons of terrorism until the invention of dynamite. Time-bombs appeared during the French Revolution; M. Chevalier, a resident of Paris, produced a cask filled with powder and missiles to which a musket barrel with trigger was attached. Saint Regent, a former naval officer, tried to blow-up Napoleon while he was first consul on the Rue Nicaise, a road from the Tuileries to the Rue Richelieu. Narodnaya Volya was the first to use dynamite on a large scale. The typical mine constructed by these Russian revolutionaries weighed over sixty pounds. The late 1800's saw a number of smaller bombs constructed, particularly by the Irish. The miniaturization of bombs presented a major technological problem in the late 19th century. The idea of preparing letter-bombs seems to have occurred first to the Russian terrorists of the 1880s. The first recorded actual letter-bomb was in June of 1895 in a Berlin post office. Today, most explosives are plastics such as RDX and PETN. Weapons have changed with the items with greater reliance and assessability of auto and semi-auto firearms and hand-held rockets. The most effective new weapon used by terrorists in the 1970s and 1980s was the car-bomb. Its continuous use and effectiveness periodically is manifested in the press.

Kidnapping and hostage-taking provide unique opportunities to the forensic investigator, particularly the

pathologist and psychiatrist-psychologist. Evidence of torture and the results of prolonged captivity have been documented and provide powerful graphic examples in the court room of the sustained trauma and provide valuable insights into the psyche of the torturer. It is important that photographs, videos and medical records accurately record such trauma. In cases where partially skeletonized remains are recovered, the forensic anthropologist working with the pathologist may often be able to determine the time of death and find evidence of injury. Radiographic examination of bone often discloses evidence of trauma which may corroborate witness statements. Often, in such cases, the greatest time is spent in making the identification of the victim. New technologies, such as DNA fingerprinting, provide possibilities only imagined previously.

In some cases, a "body" may not be available. The investigator will have to rely on any available information and evidence. Photographic intelligence using superimpositions and image enhancement often can be used to address pertinent questions posed by the investigation. This type of technology, although expensive, is not new. Image enhancement was used with great success in the investigation of the prison riots in New Mexico in which numerous victims were tortured and killed with a variety of implements which had been collected unfortunately by investigators into piles without regard to spatial relationships.

Where available, CT scans and other diagnostic radiographic modalities such as angiograms and NMR, can be used by the investigator to characterize injury patterns and possible times of injury. This capability augments medical records, autopsy reports and histological studies. Such studies appear well-suited for evaluating blunt force trauma and shrapnel injuries.

Toxicology studies are important aspects of any medicolegal investigation. It is important that sufficient specimens be obtained and that the toxicologist be informed of what substances or groups of substances are sought. The analysis of many substances, particularly naturally occurring poisons, is beyond the scope of many forensic toxicology laboratories. Available intelligence

sources in such cases should assist the investigators in these cases.

Biological, chemical and radiation threats require special consideration. Often, comparative studies are needed, expanding the scope of the investigation and the disciplines required. This often is the realm of public health officials, including veterinarians. The use of such agents are a population and environmental problem and require statistical evaluation. Unless widespread destruction is evident, only surveillance techniques and the integration of government resources will identify such threats in a timely fashion. Threats to the food chain and water supplies have the capability of extorting an entire society.

Mass disasters, particularly those caused by acts of terrorism, typically involve Federal agencies. The Armed Forces Medical Examiner's Office located at the Armed Forces Institute of Pathology in Washington, D. C. is tasked with the medicolegal death investigations coming under Department of Defense jurisdiction and is used by other federal agencies as needed through memoranda of understanding. In such cases, in addition to on-site coverage, arrangements are made to move the casualties to a Federal Port Mortuary where the identification, documentation and correlation of the victims can be accomplished using a multi-disciplinary team approach and an assembly line identification and processing process. At present, the two Port Mortuaries are located at Dover Air Force Base, Delaware and Travis Air Force Base in California. The Dover facility is particularly useful because of its proximity to Washington and the availability of a wide-range of expertise and government laboratory facilities. In addition, the base is on Federally-owned property which simplifies jurisdictional issues.

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## CRIME SCENE RECONSTRUCTION: A HOLISTIC VIEW

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Reconstruction is the process of reproducing the events and actions that occurred during the crime through examination of the evidence at a crime scene. Reconstruction involves the logical scientific interpretation of the physical and pattern evidence found at the crime scene. It answers the how in the who, what, when, why, and how series of questions that detectives ask as they investigate a crime. The holistic view of reconstruction also uses the information gleaned from other parts of the investigation to. The reconstruction analyst utilizes every facet of the investigation and reconstructs the events so that there is no conflict with evidence.

It should be understood that reconstruction is different from re-creation of the scene. One recreates the scene, through photographs or diagrams to replace everything where it was at the time the crime was discovered, or as it was when it was documented. Reconstruction of the events of the crime may depend upon the re-creation. Scene documentation upon which scene re-creation is built becomes extremely critical.

Reconstruction of the events at the crime scene will result in improvements in evidence, investigations and prosecutions. The evidence collector, whether criminalist, identification technician or detective who understands reconstruction will collect evidence in a more logical manner.

Many investigations have too much property collected in addition to the evidence. Property is those items that were collected at the scene that will not be used by anyone for any purpose whatsoever. These items must be recorded along with records of their location and disposition meaning extra work for detectives, criminalists, evidence technicians and property officers. Most police department storage areas are overflowing. Many times this property is submitted to the laboratory for examination based on there is never too much. For example, blood is collected from every spot on a wall. Examination of the pattern could show that the blood spots are cast off a tool and all came from the same source, therefore only a representative sample is really needed.

A witness describes what happened at the scene, thereby setting the direction of the investigation. The witnesses' stories should be checked against the physical evidence. A little reconstruction can save a great deal of investigatory time if the story is not true.

The prosecutor's job becomes easier if he knows what happened. He can make a more logical presentation of the case to the court. Reconstruction can be used to substantiate an eyewitness (Cortner 1987). In addition, use of a reconstruction in rebuttal can eliminate an alibi or destroy the defendant's story.

Very little has been published regarding the methodology of reconstruction as a process involving all the evidence (Findley and Hopkins 1984). Most articles regarding reconstruction are case examples (Cortner 1986; Zugibe *et al.* 1989) or involve a single type of evidence, such as the bloodstain analysis work of MacDonell (1971).

The first attempt to describe the process involved in reconstruction was by one of the earliest, but seldom recognized forensic scientists. In the early part of this century, Edward O. Heinrich conducted scientific criminal investigations in the San Francisco Bay Area. Eugene Block quotes Heinrich as he describes his investigative process in *The Wizard of Berkeley* (1958).

"Crime analysis is an orderly procedure.

It's precise and it follows always the same questions that I ask myself. Let's consider what they are:

Precisely what happened? Precisely when did it happen? Precisely where did it happen? Why did it happen? Who did it?

The average investigator seems to give immediate attention to the why and who but he takes what happened for granted. We simply must analyze the method of the crime before we can analyze its purpose and look for the criminal.

I have always held that the criminal virtually labels every crime he commits. My procedure is to reconstruct the crime by visualizing the habits and actions of the criminal. I do this by using the debris that the criminal leaves behind and relocating it with respect to the criminal episode. So I make the natural sciences interpret what I have observed."

In this description he covers all the necessary subjects, physical evidence, pattern evidence, criminal profiling, laboratory analysis, and logic to reconstruct the crime. However, it would be difficult to use the above to try to teach someone how to approach a crime scene.

Evidence needs to be classified by the role it plays in reconstruction before one can describe a process for reconstruction (Rynearson and Chisum 1989).

Evidence is related not only to the crime, it is also a product of the environment and it may change over time. To interpret the meaning of the evidence in relation to the crime we must understand the role of time and environment. We can classify evidence in relation to these factors by the following scheme:

- 1 — Predictable changes
- 2 — Unpredictable changes
- 3 — Transitory
- 4 — Relational
- 5 — Functional
- 6 — Missing or inferred.

First, we need to look at the changes that occur in evidence. These changes can be predictable and therefore useful in interpreting the evidence or they can be unpredictable and interfere with the interpretation.

Predictable changes provide valuable information regarding the time of the incident. These changes follow natural physical laws, such as the temperature equilibration of an object with its environment, that is, temperature of a dead body. One must realize the limitations of using these changes. A view of the entire scene may yield a better answer.

At one homicide scene, the pathologist was found taking the rectal temperature of the victim. To do so it had been necessary to turn the victim over and to pull her pants down. She had spoken to her daughter on the telephone only 30 minutes before her body was discovered, therefore, the time of death was limited by other information to a 30 minute period. The doctor's estimate was  $\pm 2$  hours.

Unpredictable changes are those over which we have no control. The most devastating are those which destroy the evidentiary value. This may be a subtle change in the patterns of the evidence which will result in erroneous information. An example is the change in blood patterns or destruction of blood patterns that occurs when a body is placed in a body bag and transported. The clothing of the victim can reveal the positions of the body and the actions taken after blood has started to flow. However, unless these patterns are preserved first by photography then by careful removal prior to moving the body, no interpretation is possible.

A third type of evidence that changes with time we have labeled transient. Transient evidence fades with time in a fairly rapid manner. The odors at the scene, footprints in moisture and the smoldering cigarette butt are all examples of items that must be noted by the first officer as they are no longer present when someone arrives to document the scene.

For interpretation, two other classifications relating to the role evidence plays in the crime are necessary: relational and functional. Relational evidence has meaning by virtue of its location with respect to the position of other items. The position of cartridge casings combined with the bullet paths gives a fix on where the shooter was. The blood droplet under a piece of broken glass may show the glass was broken to stage a burglary. The evidence is far more valuable due to the location of these items than in the laboratory examinations.

Functional evidence refers to the operational condition of an item. The position of the safety on a gun at a suicide, or the number of cartridges present in the magazine may be the most important part of the evidence.

An elderly man stated he went to bed early while his wife watched television. He woke the next morning to find his wife missing. She was on the living room floor with a shotgun and a bent coat hanger through the trigger. She was shot under the left arm.

When the shotgun was examined, it was found fully loaded. The husband confessed to shooting his wife. He forgot that the function of the weapon would be checked.

Observation and examination of these evidence types provides the basis for reconstruction. However, there is one other classification of evidence: missing or inferred. The objects removed from the scene by the suspect are also evidence and can be important to a reconstruction, however, the investigators have to infer what they are by the space left.

Having defined the evidence by the effect time and environment have on the interpretation, we now turn to the types of uses the evidence has in reconstruction.

- 1 — Sequential
- 2 — Directional
- 3 — Describes Action
- 4 — Defines Location
- 5 — Defines ownership
- 6 — Limits the scene.

Sequential evidence aids by establishing the order of the events. The footprint on the tire-track shows the person was present subsequent to the vehicle passing.

Directional evidence aids in determining the actions at the scene. Blood spots with their tails in the direction of travel, the ricochet pattern left by a bullet and the shoe print are all examples that show where something was going and, conversely, where it was coming from.

Action evidence are those items which show the motion or actions of the participants. These are sometimes the same as directional, such as blood drops, but can be things such as chips or indentations in a wall showing where items have been thrown.

Position is established not only by the location of various items of evidence but by their orientation at the location. A single fingerprint inside the passenger window could indicate the person was in the vehicle. However, if the fingerprint is pointed down, it may only mean that the person reached inside the glass to speak to the driver. The orientation of the toolmark on a door may show the burglary is really an insurance fraud.

Ownership or origin is usually established by laboratory examinations. Whose fingerprint? Blood? Footprint? Which tool? All are questions accustomed to being answered in the crime laboratory. The answers to these questions may be crucial to interpretation of the evidence at the crime scene.

Evidence which defines the scene is called limiting evidence. Some of these items are not thought of as evidence normally, but we record them on sketches, in photographs and on video. While the walls of a room are limits, the directional evidence may take us beyond the first set of walls into another area or room for more of the scene or even to a second scene. Whether the walls are real or some artificial points established to keep others out of the scene, we must be ready to expand them if the scene has evidence that indicates another location.

The interpretation of the evidence requires an understanding of scientific methodology, physics, psychology and logic combined with an active imagination and common sense. Understanding the culture of the participants may also be required. The reconstruction analyst is like an archeologist/anthropologist working within the framework of the very recent past.

The crime must be viewed in its entirety and the holistic view must be taken. Be careful not to refuse to accept one part of the evidence because it doesn't fit with something else. Preconceived notions quickly destroy the ability to reconstruct.

In the process of reconstruction it is necessary to listen to, or read, the statements of the participants and officers. These statements must be weighed against the evidence. Any discrepancy must be explained. Do not limit what you see by what is normal. Consider looking at things from a different viewpoint; do not draw boundaries. The following case example illustrates how one can forget that things aren't always as they seem.

Elmer and his wife Edna were out drinking. They left the bar together, arguing as usual. Thirty minutes later Elmer called to say that he had accidentally shot his wife. The police arrived, Edna was dead, shot 3 times with a .22 rifle. Elmer was arrested.

One shot was from 18 inches, entering the chest straight on. Another shot was from 12 inches, entering the chest under the right arm. Both of these shots entered the heart. The

third shot was from 6 inches away, entering the lower back and into the spine. Elmer claimed he was going to commit suicide with the rifle because Edna was berating him for being impotent. She grabbed the rifle by the barrel and it went off. Even Elmer's attorney dismissed his story.

Edna was lying on her back on the bed. Her feet were close to her shoes which she had removed and placed neatly against the wall. Her head was towards the foot of the bed. Her hands were on the wound in her back.

The bed was queen size, next to the right side of the bed was a dresser with several objects. The cartridge casings were to the foot of the bed on the left side!

This scenario has been presented in a mock crime scene to several hundred investigators, criminalists, evidence technicians, prosecutors, etc., and they always assume Elmer is lying. They refuse to see what is there. They know the cartridge casings eject to the right, therefore, they assume that Elmer leaned across the bed to shoot Edna. However, Elmer could only approach Edna from the foot of the bed. If he did so the casings would have landed on the dresser.

This inconsistency in the position of the cartridge casings is due to the assumption that the rifle was held in the normal manner. The relational evidence is changed if the orientation or directional evidence is changed. Assume Elmer is telling the truth and that he was going to commit suicide with a rifle. Hand a rifle to someone and tell them to simulate shooting themselves. Invariably, they will turn the rifle over putting their thumb on the trigger. With the rifle in this position the cartridges eject to the left as the gun is pulled by Edna. Pulling may also cause the thumb to be caught, thus causing jerking which will cause the gun to continue to fire.

To test this theory, the underside of Edna's sleeve was checked where powder was found to be present. She had her arm extended along the bullet path. Based on the experiments and hours of re-enactment with a mock up of the scene, I concluded that Elmer told the truth.

Could I prove it? No. However, I could disprove any other theory that was presented. The physical evidence fit with his story. There is more than a reasonable doubt about the intent.

Frequently the reconstruction analyst will have only photographs, video tapes, reports, sketches, diagrams, laboratory and autopsy reports upon which to build and test theories. This may not be enough, therefore a visit to the scene may be necessary to visualize the spatial relationships.

Whether he is present at the original scene or working from photos the reconstruction analyst should start

by examining the center of the action. In a homicide, this would be the body. Examine the position of the body, what is the significance of the limbs, the hair, the clothing? Look for patterns of blood flow, for gunshot residues, any of the action evidence or sequencing evidence that may be present on or around the body. Establish as much as possible about what happened to the victim. Work out from the body according to the evidence as it becomes logically apparent.

The investigator should attend the autopsy. Alternatively, he can examine the photos and pathology report so as to determine the directional evidence, that is, the direction of shots, the direction of the stab wounds, etc.

One must listen to the stories of the witnesses, the defendant and the police. The reconstruction analyst must test every story told by witnesses, defendants, and the police theories against the physical evidence. Those stories or theories that are in conflict with the evidence are false. By weeding through the alternatives, we are doing what Sherlock Holmes told Dr. Watson he was doing. "You eliminate the impossible, until whatever is left, however improbable is the truth" (Doyle 1897). The following cases shows how alternatives can be tested until the truth is determined.

The question in this case was whether the victim was shot in the front or the back. The determination of direction would determine whether the charge was manslaughter (a 3-5 year prison sentence) or murder (life imprisonment). The story of the victim's wife was in conflict with the story of the shooter, her brother-in-law.

One story was that the victim made a lunge at the gun the brother-in-law was holding. The other was that the victim was talking to his wife when, for no reason, her brother-in-law shot the victim.

A visit to the scene with the weapon and a victim of the same size allowed us to show that the back shot was consistent with the evidence. However, when we considered the alternative, the evidence was just as consistent with a frontal shot.

Unfortunately, the autopsy doctor was not a forensic pathologist. He mistook particles of lead in a section of tissue from the neck as gun powder. He also gave credence to the observation that the tissue of the neck was tucked in. He was unaware that the Sheriff had put his finger into the wound and had passed a rod through the head. He had photographed the angle of the shot. Faced with these facts the pathologist gave no opinion as to direction.

The body was x-rayed between the funeral service and interment. The x-ray showed the cone of force that points at the origin on the chin.

Thus not only were the alternative directions tested, the answer was not certain until the evidence was thoroughly documented. A miscarriage of justice was averted due to the reconstruction efforts.

Another way to test alternatives is to create a decision tree. List the alternatives that are to be considered. For example, death occurs in one of the following alternative methods, natural, accidental, suicide, or homicide. As a reason to eliminate each alternative is found it is written under the heading. When an item of evidence is found the alternatives regarding the interpretation of that item are tested against how the alternative will fit with the choice. Alternatively, finding something missing, such as the gun in a supposed suicide would indicate homicide. However, the gun could have been removed by someone from the scene. Therefore, there is an alternative to this possibility. Unless the alternative can be eliminated it must be considered. As each alternative is eliminated, we "eliminate the impossible, whatever is left, however improbable, is the truth" (Doyle 1897).

Reconstruction is like a puzzle, except the picture is not defined nor are the number of pieces specified. The analyst must be ready to change the reconstruction if new pieces are found.

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## **CRIMINAL PERSONALITY PROFILING: AN OVERVIEW**

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Analyzing a violent crime to determine identifiable characteristics of the unknown offender is not a new technique. However, the work being done by the FBI's Behavioral Science Unit (BSU) represents law enforcement's entry into this area for the first time. In the past, this procedure has been practiced primarily by clinical psychologists or psychiatrists who, while trained in matters of the mind, lacked experience in conducting criminal investigations of violent crime. As a result, their profiles were couched in terminology largely alien to the intended audience: the criminal investigator.

A criminal personality profile prepared by the BSU provides the investigative agency with characteristics of the unidentified offender that differentiates him from the general population. These characteristics are set forth in such a manner as to allow those who know and/or associate with the offender to readily recognize him.

### **INFORMATION PROVIDED IN A PROFILE**

While the format of the profile may vary with the individual preparing it, the information provided is essentially the same. Some prefer an outline format that allows the reader to identify a specific characteristic quickly without having to read through the entire report. Others prepare the profile in a narrative style. The narrative style provides greater detail and allows the reader to follow the process by which the profiler arrives at conclusions. Regardless of the format, a profile furnished by the BSU will include most, if not all, of the following information: approximate age, sex, race, marital status, occupational level, educational background, military history, socioeconomic level, pastimes or hobbies, approximate year and style of vehicle owned or operated, arrest history, appearance and grooming habits, residential information, and victim-offender relationship, as well as certain personality characteristics such as temperament, intelligence level, emotional adjustment, pathological behavioral characteristics, and ability to interact socially and sexually.

### **PROFILING AND THE BEHAVIORAL SCIENCE UNIT**

Criminal personality profiling was initiated within the BSU on an informal basis in 1972 at the FBI Acad-

emy. Faculty members would encourage their students to discuss solved and unsolved cases with which they were familiar, and as a result of such discussions, the instructors would note that in similar crimes, the offenders were a great deal alike. In subsequent classes when a student presented an unsolved crime similar to ones previously discussed, the instructors would provide verbal profiles for the student. The students would utilize the information upon returning to their agencies and would report that the use of the profiles saved many investigative manhours by properly focusing the investigation. In a few instances, a profile was credited with being directly responsible for solving the crime.

As other investigative agencies became aware of this assistance, the number of cases received for profiling rapidly increased. Since the faculty had primary responsibility of instruction, the cases were analyzed on a time-available basis. The volume of requests grew to unanticipated proportions, and in 1978 the program was formalized and submitted cases were assigned to specific individuals for profiling.

In 1981, 55 Special Agents were selected from various offices within the FBI and given 100 hours of instruction to prepare them as Profile Coordinators within their respective geographic regions. Since that time, agencies desiring this service submit their cases to the Profile Coordinator nearest them, and he in turn ensures that the materials necessary to prepare a profile have been included and that the case lends itself to the profiling process. If all prerequisites are met, the case is forwarded to the BSU and assigned for profiling. When the profile is completed, it is returned to the responsible coordinator for delivery to the requesting agency. All submitted materials are retained by the BSU for future reference.

Eventually, the caseload became overwhelming for the available BSU staff and additional personnel dedicated to profiling were necessary. In 1983, four Special Agents (Investigative Profilers) were selected to understudy the BSU faculty and assume the responsibility of profiling. In 1984, four additional Special Agents were assigned as Investigative Profilers. As a result, the backlog of cases has been reduced and more law enforcement agencies are receiving this assistance. In an effort to make this service even more available to local law en-

forcement, a one-year fellowship in profiling for police officers has been in place since 1984 (Hazelwood 1986).

## PROCEDURE FOR SUBMISSION OF CASES

Agencies desiring a criminal personality profile must submit the necessary documentation (described in the following section) to the Profile Coordinator in the FBI office nearest them. The coordinator in turn forwards the material to the BSU, where it is assigned to an Investigative Profiler. Upon completion, the profile is returned to the submitting agency through the coordinator.

### Case Criteria

The criteria for a case to be analyzed for criminal personality profiling are minimal. The case must involve a crime of violence, the offender must be unknown, and all major investigative leads must have been exhausted. While virtually any crime evincing mental, emotional, or personality aberration can be profiled, certain crimes are particularly appropriate for the process. Such crimes include a series of rapes, lust murder (mutilation or displacement of the sexual areas of the body) (Hazelwood and Douglas 1980), serial murders, child molesting, ritualistic crimes, and serial arsons.

### Case Materials

**Map.** A commercially produced map is preferred to one that has been hand drawn. A commercial map provides vital information about the locale(s) involved: deserted, industrial or residential, schools, hospitals, etc. If a commercial map is unavailable, a hand-drawn map will suffice if it is accompanied by a description of the area(s) involved. The map should be notated to indicate all significant locations, such as where the victim was approached, where the assault occurred and where the victim was left. If these locations are different, the distance between them should be stated. Any other significant locations and distances should be marked as well. For example, if the offender entered the victim's vehicle at point A, forced her to drive to point B where the assault occurred, left her there, and took her car to point C where it was abandoned, all three locations and the distances between them should appear on the map.

**Victim Statement.** The interview of the rape victim and its documentation are the most important factors in the rape profiling process. Unfortunately, the person preparing the profile seldom has the opportunity to speak with the victim and obtain those facts crucial to analyzing the behavioral aspects of the rape, and is consequently dependent upon a third party, the investigator, to

do so. For this reason, a set of questions was designed to help the investigators accomplish this task.

**Victimology.** The final documentation needed is a summary of facts known about the victim to assist the profiler in determining why the rapist behaved verbally, physically, and sexually as he did. Essential information about the victim includes: age; race; if she was with anyone at the time of, or just before the attack; her educational level; whether she appears to be passive or aggressive in nature (did she say or do something which caused the offender to become more violent?); type of employment, and a description of the socioeconomic characteristics of the area in which she resides. Of course, any other facts the investigator deems important should be included.

**Suspects.** Agencies submitting cases should not include information that identifies suspects in the matter. If a profiler is reviewing a case and it becomes clear that seasoned investigators strongly believe a particular person committed the crime, it is almost certain to bias objectivity and may result in a profile that strongly resembles the suspect.

**Nonprofileable Cases.** Not all crimes of violence lend themselves to the profiling process. There are situations or circumstances that may preclude the preparation of a valid profile. Of importance is the fact that the process is dependent not only upon the crime that has occurred and its documentation, but also upon the profiler assigned the case. In other words, what may be a difficult case or set of circumstances for one normally proficient profiler, may be quite simple for another. As an example, one person may find it extremely difficult to profile a rape in which the offender is believed to be under the influence of drugs, whereas this poses no problem for another profiler. A case in which the rapist did not speak, used minimal force, and did not engage in atypical sexual activity is extremely difficult for most profilers. Such a case would deprive the profiler of sufficient behavior to analyze. Rapes in which the victim was rendered unconscious or, because of other reasons, cannot recall details are also very difficult, if not impossible, to profile. A good rule of thumb seems to be that if factors are missing (excluding offender identification) that the officer normally needs to investigate in the case, it is not appropriate for the profiling process. It should be noted that, after conversation with the investigating officers and acquisition of additional facts, cases that had originally been determined to be inappropriate for profiling were, in fact, deemed appropriate. Prior to a case being returned as nonprofileable, it will be studied for a considerable period of time, investigating officers will be consulted, and the matter will be discussed in detail with other investigative profilers. However, the fact remains that there are cases that do not lend themselves to the profiling process.

## THE PROFILERS

When discussing criminal personality profiling, we are invariably asked what special attributes or education the profiler must possess. Our answer, quite simply, is that the successful profilers with whom we have worked possess no particular educational degree, although a background in the behavioral sciences was helpful. The qualities and attributes consistently noted in successful profilers include investigative and research experience, common sense, intuitiveness, the ability to isolate emotions, the ability to analyze a situation and arrive at logical conclusions, and the ability to reconstruct the crime utilizing the criminal's reasoning process.

### Experience

No amount of education can replace the experience of having investigated violent crimes. As an investigator, one begins to collect and store data that is automatically retrieved when a new case is opened. Experienced investigators accept nothing at face value, but instead question what is observed and go beyond what appears to be the obvious. They do not depend on what others tell them about the crime, but check and verify each piece of information. This is the most significant factor differentiating the investigative profiler from the clinical psychologist or psychiatrist who prepares profiles.

During a recent conference on treatment of sexual offenders, a rapist in the treatment program was presented to the audience. After he had departed, the treating psychologist was asked about the criminal history of the rapist. He had not previously inquired into this area, but promised to do so. Obviously he had not considered such information significant to the offender's treatment. A few minutes later, he informed the audience that the rapist had no history of arrest other than a speeding violation. When asked about the source of this information, he said it was the rapist himself!

Over a period of time, an investigator develops an ability to rise above the shock of violence and to move systematically through the often gruesome, but always necessary procedures. We are aware of individuals (not within the BSU) who refuse to examine photographs depicting homicide victims, yet prepare profiles for police agencies. It is our opinion that this is akin to performing surgery without reviewing the patient's x-rays.

### Common Sense

It has been our experience that a surprisingly large number of people do not possess the quality of common sense. There are individuals who, when confronted with

a novel situation, find it impossible to plan a strategy unless that situation is exactly like one previously experienced or learned. In law enforcement circles, such a person is often referred to as "one who goes by the book." For example, an overriding fear regardless of our best efforts is that some individuals will treat this text as a "cookbook" and, if faced with a situation not specifically addressed in these pages, will consider the entire profiling process to be of no value. It must be remembered that no two crimes or criminals are exactly alike. When dealing with human behavior, it is impossible to arbitrarily categorize that behavior. The individual who has "common sense" will recognize this and will be able to project techniques from the written page or spoken word onto generally similar situations.

### Intuition

Webster defines intuition as "the direct knowing or learning of something without the conscious use of reasoning- the ability to perceive or know things without conscious reasoning" (Webster 1972). Police officers refer to it as a "gut feeling." Like common sense, it is not something that can be learned in a classroom or from a book. Realistically, it is probably not a trait that a person is born with either, but rather an ability born from experienced, but forgotten, occurrences. Regardless of its origins, it is a fact that some individuals possess an intuitive ability that is extremely valuable in the profiling process.

Recently, a prosecutor and a detective traveled to the FBI Academy for consultation with two of the authors (Hazelwood and Douglas). The attorney was about to prosecute a man for the rape/murder of an 18-year-old paraplegic girl. The defendant had been arrested after confessing to the crime, but had refused to discuss what had motivated the murder. The prosecutor was justifiably concerned that unless he had an understanding of why the crime occurred, he would have difficulty in presenting knowledgeable and convincing arguments. After reviewing the case materials and discussing the details with the prosecutor and his associate, we felt confident in reconstructing the manner in which the crime occurred and the motivational factors involved. As he was about to leave, Douglas stated that he had "a feeling" that the date of the murder might have some significance to the killer and suggested that the attorney pursue this possibility. It was later learned that the date of the murder was the anniversary of the day on which the murderer was forced to move back to his mother's home. The mother was a very domineering person who had engaged in incest with the young man over a period of years. The defendant despised her, but was emotionally dependent on her. The prosecutor later reported that

this information played a large role in the successful prosecution of the offender.

### **Isolation of Affect**

The successful profiler is one who is able to isolate his personal feelings about the crime, the criminal, and the victim.

A 16-year old girl was kidnapped by two young men and, over a 6-hour period of time, was subjected to sexual assault and physical torture. Much of her head and pubic hair had been pulled out or burned and she had been severely beaten. She survived, but underwent hospitalization and therapy.

As just described, the case is somewhat clinical; however, the materials submitted for study consisted of graphic medical records and photographs and a detailed statement from the victim. As parents, law enforcement officers, and members of society, we are outraged at the injustice of such an attack on a child. As profilers, however, we cannot allow these feelings to interfere with the task at hand.

Personal feelings about the criminal must also be isolated. For instance, in crimes such as the one just described, one not knowledgeable about such matters might assume that the persons responsible are insane, have extensive arrest histories, and are unable to function within society. In fact, there is a very real possibility that none of these assumptions is correct. When preparing a profile, one should attempt to describe the offender as those who know him would describe him. The reader is reminded of recent and infamous serial murderers who were perfectly rational and fully functioning individuals: Kenneth Bianchi (Hillside Strangler), John Wayne Gacy, Theodore Bundy, and Wayne Williams (Atlanta murders), to mention a few.

Finally, the profiler must isolate his feelings about the victim. In many instances, the victims of sexual assault and/or homicide are what we refer to as high-risk victims. That is to say, the victims may have been particularly vulnerable because they were prostitutes, involved in drug-related activities, hitchhiking, or run-aways. If the profiler allows personal feelings about the victim to enter the evaluation, this will seriously impair the process.

### **Analytical Logic**

The ability to study a situation and arrive at logical conclusions is not one that all individuals possess. In profiling, one must make conclusions based upon what has been observed, heard, or read. A great deal of the mystique surrounding the art of profiling disappears when

realized that a large amount of the information provided in profile is arrived at analytically and logically. For example, assume a profiler had stated that the age of the offender is between 45 and 50 years. It is then quite reasonable to presume that the offender is a military veteran, inasmuch as most males within that age range served in the armed forces because of the military draft. Another example of the application of logic might involve a rapist who is believed, for one reason or another, to be employed in a white-collar occupation. It is then logical to assume that he will operate a vehicle less than 5 years of age, in that his socioeconomic status would allow him to own one.

### **View the Crime from the Criminals Perspective**

In a large metropolitan area, a series of rapes had plagued the police over a period of months. In each instance, the rapist had controlled his victim through threats and intimidation. One evening a hospital orderly went off duty at midnight and happened upon a male beating a nurse in an attempt to rape her. The orderly went to her rescue and subdued the attacker until the police arrived. Predictably, he received much attention from the news media and received a citation for bravery from the city. Shortly thereafter, the orderly was arrested for the series of rapes mentioned earlier. During interrogation, he was asked why he had rescued the nurse when he, in fact, was guilty of similar offenses. He became indignant and advised the officers that they were wrong. He would never "hurt" a woman (Hazelwood 1983, p.9)

This offender equated "hurt" with physical trauma. The point is that intent becomes clear only if we attempt to view the crime from the motivational standpoint of the criminal (Hazelwood 1983). The ability to observe the crime from the perspective of the criminal is the result of having dealt with violent crime and criminals over a period of years. It is something that can be learned in a classroom. The profiler must forget that he or she is a parent, a spouse, or a law enforcement officer, and temporarily assume the role of the criminal. Then he or she must begin to ask questions about the crime: "Why would I continue to beat the victim after all resistance had ended?" "Why wouldn't I react more violently after the victim bit me?" To assume this role is not an easy task in that violence is what we, as law enforcement officers, are charged with preventing and/or investigating.

In a recent murder case, two of the authors (Hazelwood and Douglas) provided on-site consultation. It involved the kidnap and murder of a 12-year old

girl who was found after 5 days. After the profile had been prepared and presented to the officers investigating the matter, a clinical psychologist stated that we were, in effect, describing a paranoid schizophrenic. When Douglas and Hazelwood concurred with that assessment, the psychologist asked how they could be so comfortable with that evaluation after simply studying the crime scene data. It was explained that profilers attempt to reenact the crime, to view it as the murderer did, and to reason as he did. When identified, the subject was diagnosed by psychiatrists as being a paranoid schizophrenic.

### **THE PROFILING PROCESS**

A criminal personality profile is a series of subjective opinions about the unknown individual(s) responsible for a crime or series of crimes. The process in arriving at these opinions is quite difficult to articulate in that the final product is largely dependent on common sense, intuition, and the experience of the profiler.

In preparing a rapist profile, there are three basic steps: (1) to determine from the victim what behavior was exhibited by the rapist, (2) to analyze that behavior in an attempt to ascertain the motivation underlying the assault, and (3) to set forth the characteristics of the individual who would commit the crime in a manner that explains the motivational factor indicated by that behavior (Hazelwood 1983).

In our experience, similar crimes committed for similar reasons generally are perpetrated by similar offenders. Given a rape that occurred in Houston, Texas, we can produce a rape that occurred in Arlington, Virginia, that is so similar in nature one might assume the same individual was responsible for both crimes. The explanation for this is really quite simple. Crimes are similar because the underlying motivation is basically the same; therefore, it is logical to assume that the offenders will be as similar as their crimes.

#### **Determine Offender Behavior**

It is the behavior exhibited by the offender during the commission of a crime that is studied by the profiler. In sexual assaults, the victim may be able to provide information on three forms of offender behavior: verbal, sexual and physical (force). She can advise the investigator as to what the offender said or demanded that she say, the type and sequence of sexual acts that were performed, and the amount of physical force used by the offender. Provided with this information, it is probable that the profiler can determine the underlying motivation for the assault.

#### **Analyze the Behavior**

It is at this step that one studies and evaluates the verbal, sexual, and physical behavior of the rapist, the purpose being to determine the true motivation for the sexual assault. As Groth points out, "rape is, in fact, serving primarily nonsexual needs" (1979, p.88). One should examine verbal behavior for indications of hostility, anger, a need for affection, concern, or politeness among other things. The type and sequence of sexual behavior should be analyzed, to determine whether the offender intended to degrade, involve, or punish the victim. Finally, the amount of physical force used should be studied. At what point did the rapist apply force? Was it to intimidate or punish? Did he continue to use force when resistance had ceased? One must be alert to the fact that the motivation for the crime is exhibited through the rapist's behavior.

#### **Prepare the Profile**

Once an assumption has been made as to what motivated the crime, the rapist can then be profiled. "The manner in which an individual behaves within his various environments portrays the type of person he or she is. Opinions are formed about a person's self-esteem, educational level, ability to negotiate interpersonal relationships, and goals in life by the manner in which the individual behaves" (Hazelwood 1983).

### **A WORD OF CAUTION ABOUT PROFILING**

Lecturers on this subject often begin by advising students that criminal personality profiling is an art, not a science. It is simply another investigative tool to assist in the investigation of violent crime. It is not intended to supplant any other investigative step, and in fact, we prefer not to prepare profiles until all conventional investigative procedures have been accomplished and the case remains unsolved. If an investigator depends solely upon a profile to solve his case, that investigator will have acted irresponsibly and will find this counterproductive to the goal of crime solving.

Profiles have led directly to the solution of a case, but this is the exception rather than the rule, and to expect this will lead to failure in most cases. Rather, a profile will provide assistance to the investigator by focusing the investigation toward suspects possessing the characteristics.

In an evaluation of the Criminal Personality Profiling Program, the Institutional Research and Development Unit (IRDU) of the FBI Academy surveyed user agencies as to the investigative value of profiles prepared in 192 cases. In its report the IRDU stated: "In the

192 cases examined . . . profiling helped focus the investigation in 77% of those cases where the perpetrator was identified . . . profiling was helpful . . . in that it insured a complete investigation was conducted . . . Profiling saved an estimated 594 investigative mandays and all users overwhelmingly agreed that the service should be continued" (Hazelwood, personal communication).

It should be made clear that the profile may describe more than one individual, even within the same neighborhood. In a recent rape/homicide profile that was prepared, the description matched three different individuals residing in close proximity to the victim. When the investigators confronted one of the authors (Hazelwood) about this problem, they were advised that the killer was either one of the three or someone like them. They were not particularly pleased with that piece of information, but understood that profiling is intended to identify a personality type, not a person.

As with any other human endeavor, failures will occasionally occur and this should not detract from the process. When being interviewed by Porter, who wrote an article entitled "The Mind Hunters" for the April 1983 issue of *Psychology Today*, one of the authors (Hazelwood) noted that he had prepared a particularly erroneous profile on a crime involving the assault of a mother and the shooting of her 3-month old baby. After the responsible person had been arrested and confessed, a comparison of the profile with the arrested offender revealed that it was correct in only two areas. Mention was made of that case then, and is now, to ensure that the reader does not misinterpret the value of this very subjective process. Human behavior is much too complex to categorize simplistically. To suggest that we in the Behavioral Science Unit have done so, or are attempting to do so, would not be true. Profilers are not blessed with a sixth sense, nor do we have a crystal ball that provides us with mystical powers. We are encumbered with the same human frailties as anyone else. We have simply had the opportunity to observe a very large number of violent crimes and to assimilate that experience into our work. No one is more enthusiastic about the criminal personality profiling than the members of the Behavioral Science Unit. However, we are also the first to acknowledge that proven investigative procedures, not profiling, solve crimes.

## SUMMARY

Criminal personality profiling was initiated in the FBI Academy's Behavioral Science Unit on an informal basis in 1972. The program was formalized in 1978 and again in 1983. FBI profilers were specifically assigned the task of assisting law enforcement agencies in nonfederal investigations involving crimes of violence.

The criteria for cases submitted for criminal personality profiling are that they involve a crime or series of crimes of violence that are still unsolved after all investigative leads have been exhausted.

Successful profilers are experienced in criminal investigations and research and possess common sense, intuition, and the ability to isolate their feelings about the crime, the criminal, and the victim. They have the ability to evaluate analytically the behavior exhibited in a crime and to think very much like the criminal responsible.

When analyzing a crime for profiling purposes, it is necessary to evaluate what occurred in order to determine the underlying motivation for the crime. One is then able to construct a profile of the person who would have committed such a crime for such a reason.

Criminal personality profiling should be used as an augmentation to proven investigative techniques and must not be allowed to replace those techniques. To do so would be counterproductive to the goal of identifying the unknown offender.

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## FORENSIC RADIOLOGY

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Radiology is that branch of medicine that uses ionizing radiation such as X-rays and newer modalities such as ultrasound and magnetic radiation to diagnose and treat patients. Examples of non-ionizing radiation are heat, light and sound. Traditionally radiology is divided into three divisions: therapy, nuclear medicine and diagnosis. Radiation therapy is the use of x-rays or other ionizing radiation to treat primarily malignant (cancer) and infrequently, benign disease. In nuclear medicine a radioactive material is injected into a patient to visualize an organ and to assess the function of an organ. The role of diagnostic radiology is to determine the etiology of a patient's complaint or if an injury is present. A radiologist is a medical doctor or doctor of osteopathy who has completed a residency in radiology. Just as in internal medicine and surgery, within radiology are subspecialties. Forensic radiology is a subspecialty in which radiology is applied to legal medicine including both civil and criminal applications.

Medical examiners and coroners historically have used radiology for the determination of occult injuries and the presence of foreign bodies, mainly bullets. A recent application is the detection of illicit drugs in body packers and body stuffers. A body packer is an individual who ingests packets of drugs for the purpose of smuggling (Marc *et al.* 1990). A body stuffer ingests drug packets to avoid arrest. Radiology has a minor role in ballistics and determination of manner of death.

### IDENTIFICATION

The use of x-rays for identification is little known but gaining in popularity. Actually, radiologic identification has been around for a long time. Conrad Roentgen is the discoverer of x-rays. He published his discovery in 1895 and 1896. Schuller was the first to suggest the use of x-rays for identification. In 1926, Culbert and Law published the first radiologic identification (Culbert and Law 1926, 1927). In 1944, Dutra reported the identification of a body burned beyond recognition in an automobile (Dutra 1944). Singleton was the first to radiologically identify victims of a mass disaster (Singleton 1951). This involved the Great Lakes Liner, Noronic, which burned and sank in September 17, 1947. He identified, by radiographs, 24 of the 119 victims. This technique identified more of the victims than fingerprints.

Other recent applications include the identification of victims of the crash of two jumbo jets in the Canary Island in 1977, the American Airlines Flight 191 crash at O'Hare, the crash of the military plane in Gander, Newfoundland, victims of serial killer John Wayne Gacy, and victims of political terror of the 1976-84 "Dirty Wars" in Argentina. In the Canary Island Crash, two Boeing 747 jumbo jets collided (Fitzpatrick 1984; Lichenstein *et al.* 1988; Mulligan *et al.* 1988). There were 325 American casualties. A team from the Armed Forces Institute of Pathology (AFIP) was the first to use full body x-rays on all the victims. Approximately 89% of the 274 fatalities of Flight 191 were identified. The radiologist was called in when only 50 victims remained unidentified. Twenty of these 50 victims were identified by the combined methods of anthropology/radiology. This investigation was the first to use a computer to sift ante and postmortem information and to prioritize possibilities. Of the thirty Gacy victims, six were identified radiographically. Sporadic reports of individual identifications are in the literature, some of these from a single bone (Atkins and Potts 1978; Dutra 1944; Mann and Fatteh 1968; Sanders *et al.* 1972).

Identifications are an effort of many disciplines. The team consists of a pathologist, anthropologist, odontologist, radiologist, and other investigators such as fingerprint experts and toxicologists and other specialists. The team requires a central authority to direct the investigation. This may be a medical examiner or coroner who have primary responsibility. The law varies with state and county. A spokesperson should be appointed. All communications with the press, etc., should be through this individual. The location of the investigation should be secure and with facilities for conducting the investigation. Many medical examiners offices are fully equipped with radiographic facilities. By using non-peak hours and back doors, a hospital facility can be used to conduct an investigation with minimal disturbance. In Argentina the skeletonized remains were carried in shopping bags to a local hospital for radiographing. Other types of facilities may be used or constructed. In both the Gander crash and the Canary Island crash, Dover Air Force Base was used. In the American Airlines Flight 191 crash, a remote hangar was used to conduct the investigation. A complete radiographic facility was constructed. Gurneys were used for x-ray

tables. Portable x-ray units were obtained. A dark room was constructed using a cargo container and a donated Navy processor. War stock piles are another source of equipment and supplies. Workers exposed to the ionizing radiation should be issued radiation monitoring badges. Portable lead shielding may be necessary to isolate the x-ray units from other work areas. Distance also provides radiation protection. Radiation exposure is inversely proportional to the square of the distance. For example, if the radiation is 4 rads at one meter, then at two meters the radiation would be 1/4 that or 1 rad.

Experience from different investigators involving mass disasters has taught that the initial step should be radiographing of all (Fitzpatrick 1984; Lichenstein *et al.* 1988; Mulligan *et al.* 1988) victims. Victims should be radiographed in as near as anatomical position as possible. Later, the deceased may have to be x-rayed in multiple projections for the comparison between ante and postmortem radiographs. Removal of parts of the skeleton may be necessary for accurate positioning.

The radiologist should prepare a short report prior to the autopsy indicating the remaining anatomy, evidence of pre-existing disease and injuries, location of the personal effects and foreign bodies. Estimates of age, sex, stature and race can be made from the radiograph and should be indicated. The orientation of the remaining anatomy of a markedly charred body should be indicated for the pathologist. Skeletonized remains should not be washed prior to radiographing as this removes traces of metals such as might result from a bullet.

Age is primarily estimated by the appearance and fusion of ossification centers. Bone is originally cartilage and not calcified. Almost every bone is the result of the union of several small components. These components are called primary and secondary ossification centers. The primary ossification center is the diaphysis (shaft) of a tubular bone, that is, femur or thigh bone. The secondary ossification centers are called epiphyses and apophyses. The epiphyses are at the ends of tubular bones and fuse with the diaphysis. Apophysis means outgrowth. These produce bony outgrowths such as the greater and lesser trochanters of the femur.

Age is also determined from calcification of the laryngeal cartilages, costal cartilages, and tracheobronchial cartilages. The laryngeal cartilages begin to calcify in the twenties. Costal cartilage is the cartilage connecting the sternum (breast bone) to the ribs. Costal cartilage begins to calcify usually in the early thirties. The trachea (windpipe) begins to calcify at about age sixty.

Gender can be determined several ways. Artifacts such as brassier or intrauterine contraceptive device (IUD) indicate female. Male bones tend to be larger and thicker than female bones. The shape of the male and female

pelvis differ. The female pelvis has an obtuse subpubic angle, wide sciatic notches broad iliac wings and a round pelvic inlet. The male pelvis is triangular with an acute subpubic angle and narrow sciatic notch. The male costal cartilage calcifies peripherally, the female centrally (King 1979; Navani *et al.* 1970). However, the premenstrual removal of the ovaries may result in a male pattern.

Although race and stature can be determined from an X-ray using the same techniques of the anthropologist. It is essentially always done using the specimens.

The detection of surgical sutures, clips and medical devices provide clues to an identity. In some cases, the presence of these devices and the appropriate history may be sufficient for an identification. Many medical devices have serial numbers which allow tracing to an individual patient.

Positive identification is made by comparing complex anatomical parts in the ante and postmortem radiographs. The process of comparing the antemortem to postmortem radiograph is the same as with fingerprints or dental records. In fact many dentists use the radiographic anatomy to make their dental identification. Some investigators advocate superimposition of the ante and postmortem radiographs (Atkins and Potts 1978; Dutra 1944; Sanders *et al.* 1972).

Bone is a tissue that changes with stress and age. Comparison of postmortem radiographs with antemortem radiographs from previous years or decades is a valued technique (Fitzpatrick and Macaluso 1985). In some cases adult films can be compared with adolescent or childhood radiographs. However, the nearer to birth the less likely this can successfully be done because of the rapid growth changes. Easiest bones for comparison are the pelvis and lumbar spine. In the spine one primarily uses the shape of the spinous processes, pedicles and transverse processes. Within the segments of the spine, vertebral bodies are similar in size and shape. However, the presence of osteophytes (spurs) give a uniqueness to the vertebral body. The frontal sinuses are unique in each one of us. The mastoid air cells form a unique pattern but are difficult to use (Culbert and Law 1926, 1927). The skull sutures may also be used for identification (Chandra-Sekharan 1985; Messmer and Fierro 1986).

I have used photographic techniques to improve visibility of antemortem detail by enlarging and enhancing antemortem x-rays. I am now experimenting with computer enhancement. The antemortem radiograph can be digitalized by using a special scanner. Once digitalized, it can be electronically enlarged and the data manipulated for comparison with the postmortem film. The equipment to digitalize an antemortem film is not available in hospitals, but is found primarily in research hospitals or computer laboratories of universities.

In the United States, there is not a fixed number of similarities required to make an identification. In some cases one characteristic may be so unique as to establish the identification. Usually there is an infinite number of similarities.

Potential sources to locate antemortem radiographs include places of employment, the military, hospitals, doctors and chiropractors offices, as well as an emergency medical facility.

The use of a computer saves hours by avoiding tedious manual and haphazard comparison of radiographs. In the O'Hare crash, over 5000 films were used, many with multiple exposures.

### INJURY PATTERNS

The biomechanics producing fractures are well known (Rogers 1982). Because bone is a dynamic tissue, the same event produces different injuries depending on ones age. For example, a fall on an outstretched hand produces a supracondylar (just above the elbow) fracture in a child under five. Between five and 16 years of age, an injury in the distal part of the forearm is frequently seen. Between the age of 15 and 35 a wrist fracture is common. Starting at about 40, a Colles' fracture (fracture of the distal forearm) is common. Over age 70, a fracture of the proximal humerus (shoulder) is common.

One develops an understanding of the underlying biological and mechanical factors involved in the production of a traumatic injury to the skeleton by the study of the biomechanics. The biological factors are the various gross and microscopic components. The mechanical factors are concerned with force characteristics and their resolution. The relationship between the biological system, the mechanical factors, and the resulting injuries can be expressed mathematically:  $\text{Skeleton Structure} \times \text{Mechanical Force} = \text{Injury}$ . Knowledge of two of these components allows one to predict, with some certainty, the third.

Major forces involved in fracture production are: tension, compression, shearing, rotation and angulation. Tension (tensile) forces pull an object apart or stretches it and results in a transverse fracture. Compression forces compact or squeeze an object. This produces an oblique fracture. In a shearing force, one portion of an object slides over another. A rotation (torsion) force twists an object and results in a spiral fracture. Angulation (bending) tend to curve an object. With angulation forces, the concave side is under tension while the convex side is under compression.

Biological materials, like most materials, responds differently to all types of forces. For example, materials such as bile salts and ceramics are better able to withstand compressive forces than tension forces. Ductile

materials such as copper and collagen withstand tension forces better than compression. When a deforming force is applied to biological materials exhibit differences in deformity according to the rate at which the force is applied.

Three factors involved in a fracture are age, disease and force. In an osteoporosis bone, a trivial force such as stepping off the curb may result in a fracture. As previously mentioned, the same mechanism of injury, falling on an outstretched hand, results in different fractures depending on ones age.

Injuries occur as a result of direct and indirect force. With a direct force, the fracture occurs at the point of impact. With an indirect force, the fracture occurs in an area different from where the force was applied. Fractures are further described as simple, comminute and open. A simple fracture has two bone fragments. A comminuted fracture has three or more bone fragments. An open fracture implies the fracture communicates with the skin. The term compound fracture is no longer used.

Knowledge about the etiology, factors concerning survivability, and plausibility of a suspects explanation results from the analysis of injuries of an individual, of victims in similar events, and of multiple victims of the same event (Barrie and Hodson-Walker 1970; Lichenstein *et al.* 1980; Martel *et al.* 1977; Mason 1970; McMeekin 1973; Simpson 1972). Engineering of equipment and safety procedures in transportation, sporting activities, the work and home environment have resulted from injury analysis. The injuries typical of child abuse are well known (Kleinman 1987).

To those inexperienced with roentgenographic anatomy, anatomic variants, and postmortem changes, the interpretation of forensic radiographic is filled with pitfalls (Rhodes 1970). Anomalous skull sutures and vascular grooves have frequently been reported as skull fractures. Boiling of blood produces longitudinal fractures of the long bones. In the skull, the boiling tissues and blood produce skull fractures. In some cases the intense heat may cremate all but the base of the skull. Heat coagulated blood has been reported as intracellular hematologist. In the skeletal system, heat coagulates the muscles. The flexor muscles are predominant over the extensor muscles. This results in flexing of the joints. The resulting appearance is that of a person in the fetal position or of a fighter. This position is often mistaken for a defensive position. Injuries produced by high velocity ammunition are often mistaken for torture and postmortem mutilation.

### BALLISTICS

The primary role of Radiology in ballistics is the determination of and location of missiles (Dodd and

Budzik 1990). Bullets are often deflected and end up in unexpected areas. Even with a contact shotgun wound, the pellets scatter like pool balls. The radiographic pattern is the same for contact, intermediate and distant shotgun wounds. Some handgun loads, called ratshot, contain pellets and simulate a shotgun.

The determination of caliber of a bullet is fraught with hazard (Dodd and Budzik). In the American Firearm and Toolmark Examiners Journal are four reports describing techniques and accuracy (Boehm 1980; Garland 1972; Lutz and Ward 1975; Rathman 1980). It is extremely important to account for distortion and magnification.

## SUMMARY

The identification of victims of mass disasters is important for humanitarian and legal reasons. It is important to correlate victims with their fatal environment and injuries to improve safety and engineering. In criminal cases, the feasibility of suspect's explanation may be determined by analysis of the injuries.

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# **FACIAL SCULPTURE ON THE SKULL FOR IDENTIFICATION**

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Facial sculpture, synonymous with facial reconstruction/ restoration/reproduction, is a method used in forensic anthropology to aid in identifying skeletal remains. The artist and anthropologist collaborate to construct the facial features of the unknown individual on the basis of the underlying cranial architecture.

First, the anthropologist examines the skull to determine the individual's sex and race. This is necessary because the depths of the soft tissue of the face are different in males and females of the three major racial groups. The anthropologist also provides the artist with an estimate of the individual's age at death as well as individual anatomical peculiarities, diseases and injuries that might have influenced the facial features of the person during life.

The facial sculpturing is a step-by-step procedure as follows:

The mandible is firmly attached to the cranium by gluing the condyle of the ramus in the fossa, using clay and cotton to replace cartilage. The skull is mounted on a stand, maintaining the Frankfort horizontal.

Select the correct tissue thickness table and cut cylinders of rubber accordingly. It is important to note that the tissue thickness table of measurements includes the size of the muscle, fatty tissue, and skin thickness in one calculated measurement at each landmark. These markers are glued directly on the skull. The markers are connected using modeling clay, sometimes called plasteline. The open spaces are filled, forming the shape of the face.

All of the features — mouth, eyes, nose and ears are based on measurements made on the individual skull. The location, size and shape of the features are important to the individualization of the face and must be carefully measured and located.

## **MOUTH**

The front teeth form the shape of the mouth. Three dimensions are required to form the mouth barrel:

- 1 — The depth, tissue marker #7, upper lip margin.
- 2 — The vertical thickness of the lips is measured gumline to gumline on the teeth.
- 3 — The width of the mouth is approximately the distance between two lines radiating

out from the junction of the canine and the first premolar on each side (basically, the lips cover the front six teeth).

The mouth barrel is bent around the teeth and the parting line of the lips is creased horizontally, along the halfway line and to each edge, to mark the width (or corners) of the mouth. Chin and cheek areas are connected to the mouth barrel. Lips are spread, rounded and striated to give a life-like appearance and texture.

## **EYES**

The eye is a ball, which is centered within the bony orbit. Usually, plastic prosthetic eyes can be used to give the sculpture more realism (A ball of clay can be used and the iris and pupil carved out). The apex of the cornea is approximately tangent to a centrally located line drawn from the superior and inferior margins of the orbit. The eyelids bend around the eyeballs, which give them the proper three-dimensional quality. The pupil appears to hang from the upper lid. The lower lid comes to the bottom of the iris. There seems to be no relationship between the shape of the orbit and the shape of the individual's eyelids. At best, it is important to construct the eyes to be anatomically correct. Preferably, a pleasant appearance can be given by closing the lids just slightly and forming a little puff under the eye, just as a person appears when starting to smile. The clay should be thin in the inner corner (medical canthus) of the eye and over the nasal bones. A fatty pad lies above and toward the outer side of the eye and smooths into the brow.

## **NOSE**

The nose is based on two simple measurements — the width and the projection. With these, the length of the nose is established without measuring. The width is computed: measure the nasal aperture at its widest points and increase the dimension by 10 mm for whites or increase by 16 mm for blacks. The projection (from subnasal to pronasal) is three times the length of the nasal spine, which establishes the tip of the nose. Connect the tip with the bridge and build out to the width measurement. There seems to be a possible relationship between the shape of the bridge and also the nasal spine

to the shape of the tip of the nose. The wings are rounded and the nares carved out to complete the nostrils.

### EARS

Unfortunately, there seems to be no clues about the exact shape of the ears. A rule of thumb is that the ear and the nose are approximately the same length. The ears are constructed in four steps:

- 1 — A "C" shaped bit of clay is formed to be the concha and spreads at the top forming the antihelix.
- 2 — The helix is a long thin worm-like strip, rolled and pointed at one end. Starting with the pointed end, it is curved around and fastened to the antihelix and around the concha.
- 3 — The lobule is flattened and added to the lower portion of the ear, under the concha.
- 4 — The tragus is constructed and attached, then smoothed into the cheek to complete the ear.

To locate the ear, the external auditory meatus should be at the top of the tragus. The ear is tipped back at about 15°.

At this point, the facial sculpture is finished, as far as using all of the information that the skull alone re-

veals. Normally, in a forensic case, a wig is selected using the hair sample found at the crime scene. It is a good idea to construct the neck and shoulders to drape a cloth around or to actually place a shirt or blouse, to give the illusion of a person's portrait.

Pictures of the facial sculpture are usually published in local newspapers and shown on television programs along with details of the crime and the physical evidence found. If the initial release does not produce results, sometimes it is necessary to expand the publicity to surrounding areas, neighboring states, or even nationwide.

Identification of a victim is important for at least two reasons. First, the family and friends deserve to know what has occurred. Second, to the law enforcement agency, identifying the victim can be the key to solving the crime. It is a recognized fact that a large percentage of the victims are known by their assailants.

Facial sculpture is used as a last-ditch effort when other identifying techniques such as publicizing physical characteristics, describing clothing, and searching missing persons bulletins, etc. have been unsuccessful. The outcome is uncertain in every case, but if the sculpture is done correctly and accurately as possible within the limits of the technique, it is usually worth a try.

The technique also has other applications, for instance, court exhibits, a testing device, historical projects and museum exhibits.

## FORENSIC ENTOMOLOGY: INSECTS IN THE INVESTIGATION OF VIOLENT CRIME

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The remains of a 48 year old female in a moderately advanced stage of decomposition were found in a brush-filled ditch in a predominantly industrial area outside of Honolulu, Hawaii. The body was lying face up across the ditch, which was partially filled with water. The skull was largely devoid of flesh and the mandible was separated from the skull. Three toes of the left foot were missing. The left hand was missing below the wrist, but the right hand was intact, although mummified. The remains were clothed in a blackened skirt. Upper, exposed portions of the remains were dry and partially mummified, while the lower, partially immersed, portions presented the appearance of the advanced decay stage of decomposition. Both feet were dehydrated, as were the right hand and arm. The rib cage was exposed, with some shreds of skin attached.

Further examination of the remains at the morgue revealed a largely skeletonized body lacking internal viscera and having only portions of parchment-like skin covering the neck, face and lower extremities. With the exception of a fractured hyoid bone, no evidence of antemortem traumatic injury was found, although there was some evidence of postmortem vertebrate animal depredation. Due to the presence of the fractured hyoid bone, cause of death was determined to have been manual strangulation.

Collection of arthropods associated with the remains was made during autopsy. The portions of the body that were immersed in water yielded blow fly and flesh fly larvae. The former were identified as *Chrysomya megacephala* and this identification was confirmed by rearing representative larvae to the adult stage. The flesh fly larvae were not successfully reared and the species identity remains uncertain.

A greater variety of arthropods were present on the drier portions of the remains. Larvae of the Piophilidae, *Piophilidae casei*, were present in moderate numbers along with emergent third instar larvae of a green bottle fly, *Phaenicia cuprina*. Empty puparial cases of another blow fly, *Chrysomya rufifacies*, were attached to the exposed

ribs and leg bones. Adult dermestid beetles (*Dermestes maculatus*) were present on the external surfaces of the remains and examination of the body cavities revealed a large number of both early and late instar larvae of this species. Clerid beetles, *Necrobia rufipes*, also were present on the external surfaces of the remains.

Analysis of the insect taxa and stages of development resulted in a postmortem interval estimate of 19.5 days. This estimate was based on the total assemblage of insects present on the remains and fit well with the last confirmed sighting of the decedent 20 days prior to the discovery of the remains.

The arthropods of primary significance in the post-mortem interval estimate in this case were *C. rufifacies* and *D. maculatus*, as these were the species indicating the longest period of residence on the remains. On the island of Oahu, *C. rufifacies* requires 10-12 days for development under ambient temperatures. This species is one of the first to arrive at remains and oviposition continues for the first 4-5 days of decomposition. Presence of only empty puparial cases of this species indicated a minimum postmortem interval of 16-17 days. Dermestid beetles associated with remains in the Hawaiian Islands appear between days 6-8 in habitats similar to those of this case. Late instar larvae of *D. maculatus* in the body cavities were consistent with the 19-20 day postmortem interval. Also consistent with this time period were puparia of *P. cuprina* in the soil near the remains and the clerid *N. rufipes* on the drier portions of the remains.

The partial immersion in water of these remains served to keep them in a condition suitable for oviposition by adult flies longer than would be usual in a purely terrestrial environment.

This case vividly illustrates how insect evidence collected from in, on, and around the body of a victim of untimely death, when properly collected, preserved and analyzed by an experienced and appropriately trained forensic entomologist, can provide an accurate estimate of the victim's time of death, as well as other forensi-

cally valuable information concerning the circumstances surrounding the victim's demise.

Within the United States and around the world insect scientists (entomologists) are being called upon with increasing frequency to apply their knowledge and expertise to criminal and civil proceedings and to become recognized members of forensic laboratories and medical/legal investigation teams. This need has given rise to an entomological sub-specialty termed forensic entomology.

### CHARACTERISTICS OF INSECTS

Insects are members of the class Insects in the invertebrate phylum Arthropoda. As a group, insects are probably the most successful and numerous creatures on earth. Over 900,000 species are known and it is estimated that this represents only 1/5 to 1/10 of the insect species that actually exist. Currently, there are about three times as many known insect species as there are species of all other animals combined. In just the Nearctic region (that part of North America lying north of Mexico), the insect fauna includes an estimated 125,000 to 150,000 species. In contrast, only about 3,200 species of mammals are known in the entire world.

Insects are highly adaptable creatures and can be found in nearly every conceivable habitat and situation. Annually, insects destroy millions of dollars worth of agricultural crops. They serve as vectors for the causative agents of many of the worst diseases of man and domestic animals. In addition, they bite, sting and attack man and animals directly, causing irritation, blood loss and in some cases even death.

Insects, however, are also extremely beneficial, providing such products as bee's wax and honey, silk, shellac and many of the basic components of cosmetics. For many years insects have been used extensively in the scientific laboratory and have greatly enhanced progress in nearly all aspects of biological and medical research. In certain regions of the world insects are even valued as a protein-rich food source.

Although there is much that can be said both for and against insects as they relate to man, the vast majority of insects are quite neutral, neither bestowing any great benefit nor causing any great harm.

Insects include such well known creatures as flies, mosquitoes, grasshoppers, cockroaches, termites, beetles, butterflies and moths, wasps and bees, fleas and lice. Insect adults can be differentiated from most other animals by several rather distinct traits. Among these are a hardened outer body called an exoskeleton, which is subdivided into a distinct head, thorax and abdomen; three pairs of jointed legs attached to the thorax; a single pair of antennae located on the head; large compound eyes; and one or two pairs of wings.

With few exceptions, adult insects lay eggs. Immature insects emerging from some eggs look very much like their parents, except that they are smaller in size and wingless. These immature insects, called nymphs, periodically cast their skins (moult), as they increase in size. Each stage between moults is termed an instar. Eventually, nymphs pass through a final moult and display all of the characteristics of adults. Grasshoppers, cockroaches and the young of several other groups grow in this gradual fashion.

Most insects, however, pass through three very dissimilar stages during their development, namely egg, larva and pupa. None of these stages bears any resemblance to any other stage or to the adult. Larva, which hatch from these eggs, are often soft-bodied and resemble caterpillars, maggots, or grubs. As they grow, these larvae can cast their skins (moult) as they increase in size. The number of larvae moults varies dramatically from insect group to group. Eventually, however, these larvae surround themselves with a hardened cocoon-like outer skin in which they undergo their final pre-adult development. This stage is called the pupa. Fully formed adult insects eventually emerge from the pupal enclosure. Butterflies, moths, flies, beetles and numerous other insect groups develop in this manner. Most of the forensically important insect species pass through this latter type of development.

### INSECTS AND HUMAN DECOMPOSITION

Apart from the bacteria and fungi, insects are the most important processors of dead animal remains. A wide variety of carcass-frequenting specialists utilize decomposing materials both as a food source and as a place to rear their young. Animal studies have shown that carcasses left uncovered and freely exposed to insects lose up to 90% of their weight within a week during summer months. In contrast, carcasses covered with mesh to prevent insect access, gradually dry out and mummify over a period of more than 100 days.

Because decomposing animal remains occur relatively infrequently and are widely scattered throughout the environment, insects which specialize in utilizing these resources have evolved highly developed methods of carcass detection (smell) and locomotion (flight). Initially, strong flying insects, particularly flies, are attracted to the odors produced by gases and body fluids oozing from the natural body openings and to blood escaping from wounds. In time, the skin, underlying organs, flesh and bone become attractive to other groups of scavenging insects. Insects are responsible for the consumption of virtually all parts of the carcass except the skeleton. As a carcass decomposes, therefore, it can be viewed as a succession of habitats each attractive

to, and supporting, a different group of specialized insects. Although the exact species may differ from country to country, from habitat to habitat, and from season to season, the basic pattern of the succession of insect decomposers is remarkably constant around the world.

Human corpses, whether they have been produced naturally or as the result of foul play, are processed by these insect decomposers in the same manner as any other piece of animal carcass. Forensic entomology, therefore, is based on the analysis of the insects and other invertebrates which sequentially colonize a corpse as decomposition progresses and on the rates at which the various stages of their offspring develop. Entomological information can be extremely useful in determining manner of death, movement of a cadaver from one site to another and length of the post mortem interval.

### THE IMPORTANCE OF BLOW FLIES

While a wide variety of insect species are attracted to decomposing remains and play an active role in the decay process, two groups, the flies (Diptera) and beetles (Coleoptera) are of major importance in most circumstances. Diptera (flies), whose larvae are capable of living in a semi-liquid medium, are the first insects to be attracted to and colonize decomposing remains. Fly larvae (maggots) are responsible for the dramatic consumption of the cadaver's organs and tissues. Only much later, when the corpse has to a large extent dried out, do the species of other insect groups, notably Coleoptera (beetles) move in and continue the process.

Large, strong flying, highly mobile flies are typically the first insects to be attracted by the faint aromas emanating from a fresh corpse. Blow flies (family: Calliphoridae) frequently arrive within minutes to a few hours after death and are generally the first individuals to arrive at a crime scene. Blow flies arriving at a corpse either begin to lay eggs immediately, or first feed on the protein-rich fluids emanating from the corpse and then begin oviposition. Initially these flies feed and lay eggs in the natural body openings (ears, eyes, nose, mouth, and if exposed, the anus and genitalia). This is due to the fact that blow fly adults have soft, tongue-like mouth parts which are not capable of piercing human skin. Natural body openings also provide moist, humid cavities which enhance egg hatching and larval survival.

Blow fly eggs are small (2-3 mm), whitish-yellow and somewhat elongate. They are frequently packed into natural body openings in large numbers and are easily visible to the naked eye. During colder months, however, their numbers may be few and they may be difficult to locate, being hidden in more cryptic sites such as under the eyelids or within the nostrils. Blow fly eggs

will typically hatch within one to three days, depending on species and environmental conditions.

When blow fly eggs hatch, they produce small, relatively featureless, worm-like creatures called larvae or maggots. Blow fly larvae have a tapered anterior end containing a pair of mouth hooks which the larvae use in feeding and also for locomotion. Posteriorly the larvae bear a pair of flattened nostrils called spiracles, through which they breathe. These features, along with the larvae size and shape, provide important diagnostic features.

The larvae grow rapidly, passing through three moults (instars) before becoming fully grown. Large numbers of larvae typically hatch together and move around the corpse as a group. Blow fly larvae are responsible for disseminating bacteria and secreting enzymes which enable them to consume virtually all of the soft tissues contained within the corpse. Blow fly larvae become fully grown within several days to several weeks depending upon species, environmental conditions and the number of larvae present.

After reaching the third instar, larvae undergo a dramatic behavioral change in which they crawl away from the corpse, burrow down into the soil and pupate. As previously mentioned the process of pupation involves the secretion of a hardened outer skin or casing around the body of the larvae. Within this pupal case the larvae undergoes complete physical reorganization and eventually emerges bearing all of the adult fly characteristics. Blow fly pupae are small, football-shaped structures which are reddish to dark brown in color. Pupal cases are extremely resilient and will in some cases remain in the soil beneath the corpse for hundreds of years. Blow fly pupal cases can supply valuable information long after the remains of the body have decomposed. Only through careful examination of the soil, either the corpse or at a site where a corpse is reported to have decomposed, will this valuable entomological evidence be found.

Blow fly species differ in their abundance from region to region, from habitat to habitat and from season to season. In the northern U. S. for example, the blue blow fly, *Calliphora vicina*, is most abundant during the cooler parts of the year whereas the bronze blow fly *Phaenicia sericata*, dominates corpses during the warmest parts of the summer. Similarly the green blow fly, *Lucilia illustris*, frequents corpses located in open, brightly lit habitats whereas the black blow fly, *Phormia regina*, prefers shaded localities.

The careful analysis of the physical characteristics of the various developmental stages of the blow flies inhabiting the corpse, when coupled with the detailed knowledge of their ecology, and the environmental conditions to which they are exposed, can provide forensic

investigators with meaningful information concerning the time of death, movement of the corpse from one site to another and manner of death.

### **BEETLES AND THEIR ALLIES**

Following the invasion of the corpse by blow flies, a wide variety of other types of insects also colonize the remains. Carrion beetles, rove beetles, clown beetles, sap beetles, checkered beetles, scarab beetles and dermestid beetles all become members of the host corpse community feeding and rearing their young on the drier remaining tissues and on the large maggot mass. Additionally, other types of flies including house flies, flesh flies, skipper flies, fruit flies and coffin flies also colonize the remaining tissues. The corpse eventually comes to support a complex and diverse community of insects often numbering hundreds of species and thousands of individuals. These insects, while far less numerous than the blow fly larvae which originally colonized the remains, can be seen flying, crawling and scurrying about the corpse itself and in the soil beneath the remains.

As previously mentioned these insects are attracted to the corpse in an orderly, progressive fashion. The successive nature of the colonization process enables forensic entomologists, when supplied with a representative sample of the insects present, to provide investigators with forensically meaningful information concerning the circumstances surrounding the demise of the individual. Essentially, by knowing the players on the field at the time that the corpse was found, forensic entomologists are able to determine the inning of the game.

### **COLLECTION AND PRESERVATION OF SPECIMENS**

Accurate forensic determinations depend upon the proper collection, preservation, and rearing of entomological specimens. In order to accomplish this, investigators must be able to recognize adult and immature stages of locally abundant, carrion frequenting insects and be familiar with the proper techniques for collecting and preserving these animals. Representative samples of all adult and immature insects should be collected from on, in and beneath the corpse. Flying insects can be collected with the standard insect or short-handled hand net. It is important to make collections as soon as possible as specimens of adult flies may leave the area surrounding the corpse when human activity becomes evident. Once collected adult specimens can be retained indefinitely for analysis. Adult flying insects can be immediately placed in 70% ethanol or isopropyl alcohol diluted 1:1 with water. Higher concentrations of isopro-

pyl alcohol may cause specimens to become brittle. Do not use formalin to preserve insects, unless no other preserving fluid is available. Insects preserved in formalin should be transferred to 70% alcohol as soon as possible. A small hand net and preserving fluid can easily be carried as part of standard equipment.

Crawling insects from the surface of and within the corpse should be collected using forceps or the fingers. During sampling, hands should be protected with surgical gloves at all times. Smaller specimens (under 5 mm) can be collected with a small artist's paint brush dipped in a preserving fluid. Crawling insects located on the ground beneath the corpse can most easily be collected by scooping up the top few centimeters of soil and placing it in a plastic bag. The plastic bag containing the soil should be chilled, if possible, until the insects are extracted and preserved to prevent further growth and possible predation or asphyxiation. This is particularly important when large numbers of fly larvae are present.

As previously mentioned, some insects, particularly mature fly larvae and beetles, will burrow into the soil beneath the corpse. A careful examination of the soil beneath the corpse is important particularly in cases of advanced decay. This analysis is most easily accomplished by removing large samples of soil from beneath the area where the corpse was located. These samples should be placed in plastic bags and refrigerated until they can be processed by a trained entomologist or laboratory technician.

When skeletal remains are encountered in the field, a close examination of the bones and surrounding soil must be made prior to skeletal removal. Close examination of bone cavities will usually produce numerous insect remains. The skull should be most closely examined, particularly inside the cranial vault. The skull should be placed on a white sheet or large piece of white paper, and the eye orbits, nasal openings, cranial vault and auditory meatus probed with a pair of forceps and a penlight. The interior of the skull can then be gently washed inside and outside with water, while being held over a small collection screen or cheese cloth.

Immature and soft-bodied insects, particularly the larvae of blow flies, are critical to an accurate forensic analysis. Representative samples of fly larvae, including the largest individuals present, should be collected and immediately subdivided into two subsamples. One subsample can be preserved immediately and the other should be saved alive for rearing to adult stages. Sufficient numbers of individuals should be collected to ensure that a representative sample of the insect population is present. Samples of fly larvae to be immediately killed can be preserved by placing them in hot water (77°C) for two to three minutes and then transferring them to 70% ethanol. Various alternative larval preservatives can be

used, depending upon the availability of the chemicals. Specimens for rearing should be placed alive in small ice cream cartons or similar containers 1/4 to 1/2 filled with a coarse inert material such as vermiculite. Moist soil can be used if other materials are not available. Do not put living specimens to be reared in sealed plastic bags or sealed vials for longer than 12 hours, since they do poorly in such environments, especially in warm weather. Transport living material by the fastest possible means to a rearing facility. Use of the regular mail service usually is not suitable for transporting living material.

Immature flies can be successfully reared on diets of beef liver, or on small pieces of musculature obtained from the corpse. Larvae should be gently transferred with forceps onto the dietary material which has been previously placed atop a 4–8 cm deep container filled with damp, coarse soil or vermiculite. Small glass dishes, 8–10 cm in diameter, or *breakers* are suitable. These cultures should contain 15–25 larvae each. Larval activity should be checked daily and a record of larval size and instar recorded. Additional liver can be added to these cultures as needed. Mature larvae will migrate downward into the substrate and pupate. Adult flies will eventually emerge, crawl to the surface and attempt to fly away. Because of this, rearing containers should be placed inside standard insect-rearing cages or other mesh containers that will prevent adult flies from dispersing.

Whenever possible, fly larvae should be reared in climatic conditions approximating those to which the corpse was exposed. Environmental chambers are useful, if available. Temperature is the most critical factor. Calculations of the average time interval required for each developmental stage (larval instars, pupa and adult emergence), allow accurate determination of corpse colonization and time of death.

It may be helpful to allow emerged adult flies to feed for 24 hours on a cotton pad or ball soaked with a small amount of Gatorade®. This insures that their outer skins will harden and accurate species identifications can be made. Emerged adult flies can be placed in 70% ethanol or pinned and stored in insect boxes. Immature beetles need not be reared and should simply be placed in 70% ethanol for identification.

Additional observations concerning any other kinds of animals and plants found in and around the corpse may provide supplemental information about the time, cause and location of death. Collect samples of any unusual specimens such as ants, fleas, body lice, seaweeds, etc. Likewise, representative samples of specimens encountered at autopsy should be collected for analysis. Any specimens collected during the autopsy can be processed as previously described. Marine and aquatic plants and animals are best preserved in 10% neutral buffered formalin.

Containers which contain preserved and living specimens should be labeled in the following manner.

- 1 — Date collected
- 2 — Time collected
- 3 — Location of remains (as precise as possible)
- 4 — Area of the body infested
- 5 — Name, address and telephone number of the collector

If specimens are to be shipped long distances for analysis, package containers and vials of preserved specimens in well-cushioned boxes to avoid breakage and ship by the most convenient means. If shipped by regular mail, wrap each vial individually in a padding material such as cellu-cotton and place each vial individually in a box surrounded by styrofoam chips on all sides. This will minimize the possibility of breakage during shipping. Clearly mark the box "Liquid in Glass". This will generally receive gentler handling by the Post Office.

Containers of soil samples and other living specimens should be kept in relatively cool, well ventilated environments. Time is critical if accurate information is to be obtained from living material. Thus, these materials must be shipped by the most rapid means.

As with other types of physical evidence, take care to insure a continuous, well documented chain of legally acceptable evidence possession.

## DESCRIPTION OF LOCALITY

An accurate, detailed description of the habitat in which the corpse was found is important to forensic entomologists. Whenever possible, written descriptions should be accompanied by a complete set of crime-scene photographs which illustrate the general habitat type, the terrain, the type of vegetation, type of soil and the extent to which the corpse is exposed to sunlight.

Detailed photographs of the corpse are also necessary including photographs which illustrate the sex, age, height and weight of the remains, the presence and extent of clothing, the orientation of the corpse when found, the extent of trauma, the extent and degree of decomposition and close-up photographs of the inhabiting insects.

Because climatic conditions have a profound affect on the development of immature insects, the most accurate data available describing these conditions at the location where the corpse was found is of critical importance. Whenever possible, record maximum and minimum temperature values at the scene as soon as possible after discovery. Obtain climatic data from the nearest National Oceanic and Atmospheric Administration (NOAA), weather station, for the entire estimated post mortem period and for a two to three week interval

before the estimated time of death. Additionally, any information available concerning daily rainfall, cloud cover and wind speed and direction should be obtained if available.

### ADDITIONAL CASE HISTORIES

In early Spring, the fully-clothed body of a young, white male was found in a sandy, shrub habitat, in the southwestern U. S. The victim had died of multiple gun shot wounds to the chest and back inflicted by a small caliber hand gun. While little evidence of decomposition was evidenced externally, a small amount of blood was observed to have oozed from the victim's left nostril and partially coated his left eye.

Crime scene investigators noted and collected a small atypical granular mass from the surface of the victim's left eye. Examination of this substance in the crime laboratory a short time later revealed the material was a small mass of blow fly eggs and that several had hatched.

The newly hatched blow fly larvae were allowed to grow and were subsequently identified as *Cochliomyia macellaria*, commonly known as the secondary screw worm. Based on the climatic conditions to which the corpse was believed to have been exposed and a knowledge of the developmental biology of this fly, it was determined that the eggs had most likely been laid on the corpse for 24 to 36 hours prior to the time the body was found. Subsequent investigation determined the victim's identity and the fact that he had last been seen alive in the company of a male companion approximately 36 hours prior to the time his body was found. It was later determined that the victim had been murdered by his companion about 36 hours prior to his detection.

In this case, blow fly eggs, collected from the remains and analyzed in a timely manner, provided investigators with an accurate estimate of the post mortem interval and allowed them to more narrowly focus their investigative efforts enhancing their ability to identify the victim and to bring the case to a reasonable solution.

Similarly, in early summer, the body of a young, unidentified white female was found at the end of a logging road in a rural section of the northeastern U. S. Investigation revealed that the unidentified young woman had died from a single gunshot to the right side of the head inflicted by a 12 gauge shotgun. While processing the crime scene, investigators collected representative samples of adult and larval blow flies which had infested the area of the wound.

These specimens proved to be mature larvae and adults of the black blow fly (*Phormia regina*). Following an indepth review of climatic conditions, habitat characteristics and crime scene photographs, entomolo-

gists estimated that the young woman had been killed about five days prior to her discovery and that her body had been placed in that location close to the time of her death.

Based in part on the entomological analysis, investigators circulated requests for reports of missing persons fitting the deceased's description who had disappeared five days prior to the corpse discovery. Eventually, the young woman was identified and her boyfriend became the prime suspect. Just prior to his arrest, however, he was found hanged in a motel. A suicide note revealed that he had murdered the victim five days before her remains were found and had committed the homicide at the end of the logging road where she was discovered.

In late summer, a 37-year old black male was found in Kawaiui Marsh, a swamp located approximately 1.6 km from the ocean on the windward side of the island of Oahu, Hawaii. The elevation for the site was only slightly above sea level. The body was clothed in blue jeans and a t-shirt. There was a gunshot wound to the right frontal skull.

The corpse was in an advanced state of decay. The skull was largely devoid of flesh, although some was present on the lateral surfaces and the ears were relatively intact. The cervical area was largely devoid of flesh and the vertebrae were clearly visible. The groin area was largely decomposed and contained a large number of Diptera larvae. On autopsy, no penetration of the abdominal cavity by larvae was observed. Collections of insects from the remains yielded two species of Calliphoridae larvae. *Chrysomya megacephala* was represented by third instar larvae from the chest, groin, and legs, while *Chrysomya rufifacies* was represented by second instar larvae and third instar larvae from the chest. None of the larvae from either species were in the prepupal stage.

Temperature data were obtained from the nearest weather station and climatic information from this station was analyzed for the time period in question. This analysis, when coupled with the developmental stages of the specimens collected, suggested a minimum postmortem interval of approximately 117 hours.

A subsequent investigation revealed that the decedent had last been seen at about 6:00 p.m. six days previously as he departed for work. He failed to arrive at work as scheduled at 8:00 p.m. When his remains were discovered they were placed into a refrigerated crypt. As species *Chrysomya rufifacies* do not form dense maggot masses, activity for this species would have ceased shortly after the remains were placed into the refrigerated crypt. The post mortem interval based on insect age in this case was about 117 hours and fit well with the last sighting of the decedent and his failure to report for work.

In the southeastern U. S., police were called to investigate a foul smelling odor which was emanating

from a small single family home in a rural section of town. Investigating officers soon discovered the badly decomposed body of a young, black female in a shallow grave in a dirt basement of the dwelling.

The victim had died of a single gunshot wound to the head, inflicted with a small caliber rifle. Subsequently, a careful examination of the corpse and a detailed excavation of the soil in and around the grave site revealed the presence of numerous larvae of the blue blow fly, *Calliphora vicina* and larvae and pupae of a relative of the house fly, *Synthesiomyia nudesita*.

Specimens collected from the scene were reared in the laboratory to adults. Supplemental information including climatic data and soil temperatures were reviewed in an effort to determine the climatic conditions to which the developing flies were exposed. Using information on the developmental biology of both of these species of flies, forensic entomologists were able to estimate that the victim had died and was colonized by flies approximately 15 days prior to the time that she was found.

Once provided with this information, investigators were able to target their investigation in and around the time of the victim's demise. Shortly thereafter a suspect was developed and this individual eventually confessed to having killed the victim 28 days prior to the time the body was located and having attempted to bury the victim in a shallow grave located in the basement of the house shortly after committing the homicide.

The remains of a female child (30 months of age) were recovered from a shallow grave on a narrow ledge on the side of Koko Head Crater, Oahu, Hawaii. The skeletonized remains were buried in dirt and gravel and some bones were partially exposed. Other bones were scattered on the surface. The skull was facing upward and the mandible was located several feet from the skull. Also present in the grave were four small stuffed dolls.

Examination of the remains at the morgue revealed largely skeletonized material. Present were the skull and mandible, most of the ribs, many thoracic vertebral bodies, the mostly skeletonized pelvis and lower extremities, the left humerus, radius, ulna and scapula. Absent were many of the cervical vertebrae, right upper extremity and scapula. Small bones of the left foot appeared to have been chewed and showed signs of postmortem animal depredation, as did the bones of the left forearm. Apparent scalp hair remaining adjacent to the skull was blond and straight and measured up to 15 cm in length. Clothing accompanying the remains in which the corpse had been buried were a hooded jacket and a pair of running shoes. A second search of the dangerously precarious burial site the day following the recovery of the remains yielded the right scapula and arm as well as additional vertebrae.

Examination of the remains at the morgue yielded a limited assortment of arthropods. Empty puparial cases of the calliphorid *Chrysomya rufifacies* were attached to the skull under the scalp, which had been largely eaten away. Adult dermestid beetles, *Dermestes maculatus*, were present on the bones and the late instar larval skins of that species were observed in areas under the scalp, inside the cranial cavity and on the femurs. These cast larval skins of *D. maculatus* were in good condition and did not appear to have been exposed to weathering effects for any period of time. Larval scenopinids (Diptera) were collected from the skull near the bases of the hair. Adult clerids, *Necrobia rufipes*, were recovered from the bones of the left foot. A silverfish (Thysanura: Leptismatidae) was recovered from the body bag.

In the hood of the jacket, there was a quantity of soil associated with the remains. This was processed in a Berlese-Tullgren funnel and sorted by hand. This sample yielded additional larval scenopinid and adult *D. maculatus*. There was an adult histerid beetle which represents an undescribed species. Mites associated with this sample included species in the families Acaridae, Histiostomatidae, Macrochelidae, Pachylaelapidae, Uropodidae and Winterschmidtidae.

Comparison of this assemblage with results of earlier decomposition studies conducted in xerophytic habitats on the island of Oahu resulted in a postmortem interval estimate of 52–76 days. This estimate was lowered to slightly over 52 days, based on the condition of the cast larval skins of *D. maculatus*. In the decomposition studies used for comparison, the last observed larval activity for *D. maculatus* was on day 51. The cast larval skins of *D. maculatus* disintegrate quite rapidly when exposed to weathering. The fact that these skins were in excellent condition and easily identifiable to species level indicated that they had been shed recently.

The window fly larvae (Scenopinidae) were all late instars and of a size comparable to those collected from decomposition studies on day 51 in one study and day 48 in another. This tended to reinforce the estimate of slightly over 52 days. The mites recovered also were consistent with this time frame and the absence of any beetle mite species was indicative of the shorter portion of the computer estimate. The final postmortem interval estimate of slightly over 52 days for this case fit well with the interval established independently by confession of the suspect in the case.

Several years ago a young woman was attacked and brutally raped in a suburban Chicago wood lot by a man wearing a ski mask. Investigators quickly developed a suspect and armed with a search warrant seized a ski mask similar to the one described by the victim from the suspect's apartment. When questioned about the ski mask, the suspect informed investigators the ski mask was

indeed his but that it had not been used since the previous winter.

Investigators observed large numbers of cockle burrs and other vegetation attached to the surface of the mask. The mask and its associated vegetation was brought to a forensic entomologist for analysis. Following a careful dissection of the cockle burrs attached to the mask, the entomologist was able to locate several small caterpillars inside the vegetation. The insects were subsequently identified and information concerning their development collected and reviewed.

It was subsequently determined that the caterpillars within the cockle burrs had a one year life cycle, with adults being active in the spring, laying eggs in early summer, larvae or caterpillars developing within the cockle burr vegetation during mid to late summer, undergoing pupation during the winter and emerging as adults the following summer. The entomologist was thus able to inform investigators that the ski mask had been present in the outside environment during mid to early summer of that year around the time the rape occurred. Armed with this information, investigators confronted the suspect and he subsequently confessed to having committed the rape.

In this case analysis of vegetation associated with evidence collected from a crime scene enabled investigators to accurately link the suspect to the crime at or about the time of the crime.

Recently, several small children were brought to a local hospital emergency room suffering from widespread diaper rash, malnutrition and generalized neglect. A physical examination revealed that the anal and genital areas of these children were infested by fly larvae. Samples of the invading fly larvae were collected, preserved and forwarded to forensic entomologists for examination.

An analysis of the fly larvae infesting the young children revealed that they had been present on the children for a minimum of four to five days. This information was used as an indicator of the minimum amount of time which had passed since the children had their diapers changed and were properly cleaned and cared for. The entomological information was the only data available which provided quantitative information accurately determining the length of time the children had been without care. The entomological evidence provided crucial information in subsequent hearings concerning the welfare of the children.

## CONCLUSIONS

Forensically important insects can be a powerful tool in investigations of homicide, untimely death and other violent crimes. Accurate forensic determinations are possible, however, only when representative specimens are recognized, properly collected, preserved and forwarded in a timely manner to qualified forensic entomologists for analysis. Prosecutors, police, pathologists and others involved in solving violent crimes should become fully aware of the complex ecology of the decay process, the important role which insects play in decomposition and necessity of collecting representative specimens and supplemental field data.

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## **DENTISTRY'S ROLE IN MASS DISASTER VICTIM IDENTIFICATION A MILITARY DENTIST'S PROSPECTIVE**

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What constitutes a mass disaster is, according to some, dependent upon the capacity of those whose responsibility it becomes to identify and process the remains of the victims. An accident which results in 30 lives lost might be considered a minor logistical demand should the victims be returned to an established full scale mortuary facility such as is located at Dover Air Force Base in Delaware; whereas that same number of victims might severely tax the capability of much smaller morgues of a military hospital elsewhere. Certainly by magnitude, the loss of life associated with the United States Marine Corps peacekeeping force serving in Beirut, Lebanon, the United States Army 101st Airborne Division peacekeeping force returning from duty in the Sinai in 1985 or the crews serving aboard United States Ships Stark and Iowa would all be considered military mass disasters. Are these remains to be treated differently from the manner in which two bodies recovered from a crashed F-15 Eagle fighter or that of a returned MIA might be treated? It is hoped not. In all these situations the role of the military dentist is to become part of a standardized method in which multiple disciplines attempt to achieve positive identification of every victim, in order that the next of kin may complete the grieving process and continue with his or her life. It is the final act of patient care that the military dentist can provide to the service member.

The Office of the Armed Forces Medical Examiner, located at the Armed Forces Institute of Pathology (AFIP), has specific protocols which are followed in mass disasters. The dentists assigned to participate with that office in mass disasters, likewise have certain standards which are expected to be met. The remainder of this discussion will center on those dental procedures which have application to both military and civilian mass disasters.

To reiterate a central point, forensic dentists are only part of a team which also includes search and rescue personnel, fingerprint experts, photographers, radiologists, forensic pathologists, toxicologists, anthropologists and many others trying to achieve a common goal of victim identification. Dentistry's role in the identification procedure is an important one, particularly when visual or fingerprint confirmation cannot be performed based on condition of the body. The keys to

successful utilization of dentistry in mass disaster situations are prior planning, acquisition of good antemortem dental records for comparison purposes, and shared communication with other sections in the identification process. The bottom line is teamwork.

Planning for a mass disaster is paramount to successful response when tragedy strikes. At the AFIP, a roster is maintained of military dentists experienced in victim identification, as well as contact points from which augmentees could be obtained as needed. Dental equipment and supplies are pre-packed in kits based on number of victims reported, enabling rapid response to disaster situations. Certain equipment, such as lead screens for the dental x-ray area, is pre-positioned in a secured location at the Dover Air Force Base mortuary for future use. Mere planning is not the panacea to successful operation of a mass disaster mission however. Practice perfects. It is far better for the dentist to make a mistake in identification in the relatively non-stressful environment of the AFIP dental identification laboratory, than when in an actual mass disaster operation.

In a mass disaster, dentistry's role begins not at the body identification center, but rather at the crash site. It is imperative the search team be briefed on recognition and protection of dental evidence. In aircraft or other high velocity vehicle accident, explosion and fire can result in fragmented and charred dental structures. This might cause searchers unfamiliar with human dentition in this state to overlook important evidence. It is therefore recommended that all burned structures which might prove to be dental evidence, particularly those which superficially appear to resemble shards of coal, be radiographed to determine if they are, in fact, human teeth. Furthermore, to prevent post mortem tooth loss from the jaws, each head or disassociated jaw should be wrapped prior to removal from the disaster site. This procedure will preclude lengthy delay at the identification center to search the remains and body bag for missing teeth.

At the identification center, the dental section is divided into four teams. They are the post mortem, antemortem, records comparison and administrative teams. The requirement for sufficient dental personnel to field these teams is determined by the number of victims received. A suggested generalized recommendation for staffing mass disasters might be: one oral maxil-

lofacial surgeon for every 50 fatalities, one general or restorative dentist and one dental assistant for every 15 fatalities, one experienced dental x-ray technician capable of exposing diagnostic quality dental radiographs for every 25 fatalities and one dental section leader, records custodian and computer operator.

The post mortem team is further subdivided into three areas of responsibility: surgical exposure, radiographing and clinical examination of the dentition. All personnel involved with remains contact should take appropriate precautions to avoid exposure to hepatitis and human immunodeficiency virus. In cases where fire has rendered the body non-viewable, facial soft tissues are resected and the jaws disarticulated to facilitate examination. Viewable remains are obviously not subjected to any facial surgical intervention prior to obtaining dental radiographs and clinical examination. In these cases if rigor mortis has not broken, wooden tongue depressors are gently inserted between the victim's maxillary and mandibular teeth until adequate access is obtained, taking care to avoid tearing the lip commissures.

Safety standards to protect dental personnel from radiation hazards must be met prior radiographic survey of the victim's dentition. Correct periapical x-ray film positioning is often difficult to achieve, therefore, gauze pads or modeling clay can be used to achieve the desired result. To avoid commingling of post mortem radiographs of two or more victims, all exposed films from each victim are inventoried prior to and following development before another victim's radiographs are processed. Quality assurance of developed films is accomplished before a telephone or intercom message is transmitted from the darkroom area to the dental x-ray suite that the body may be moved to the next station. Medical radiology may become important in discovery of displaced dental structures prior to the clinical post mortem examination.

At the dental examination, the teeth are gently cleaned with alternating solutions of hydrogen peroxide and diluted bleach. Intraoral photographs are taken to document the clinical findings. Mental and physical fatigue of the examiners are potential causes of error in creating the post mortem dental record. A system which utilizes multiple verifications of clinical findings and the subsequent recording of those findings reduces this possibility.

Management of dysphoria or post traumatic stress syndrome by identification team members in mass disaster situations is an important concern. Evidence of this condition may include acute and latent episodes of depression, insomnia, nightmares, flashbacks or re-visualization of events, drastic mood swings, and loss of coping skills. To minimize this potential problem, it is recommended that all participants receive an introduc-

tory briefing which accurately details anticipated conditions. It is a responsibility of all members of the dental section to monitor themselves and others for signs of this condition. It is often helpful to provide a goal which individuals can work towards, as well as encouraging the opportunity to express their feelings and concerns. Varying personnel assignments and introduction of music or humor into the work place may also mitigate this condition.

The antemortem team faces the most demanding task in the dental area of operation. It must create a record which can easily be compared with the post mortem dental record. Standardization of forms and terminology with the post mortem dental record is therefore required. The most significant problem in mass disaster victim identification from the dental prospective is, in the AFIP experience, poor quality or lack of antemortem dental records. Although the armed forces dental services of the Army, Navy and Air Force employ a standardized method of charting on a single type of form, the military dental treatment record is a cumbersome document and must be summarized into a short composite form namely the antemortem reconstructed dental chart. In the civilian sector, the methods of charting and forms utilized are sufficiently different from the post mortem dental form so as to require similar reconstruction. Usually, the dental treatment chart and antemortem radiographs provided sufficient information for this process. Supplemental sources of dental data to augment inadequate dental records might include: skull radiographs from hospital admissions such as might be taken following a motor vehicle accident, dental casts, dental prosthetic prescriptions, duplicate prostheses, portrait photographs, and medical records. A sequestered environment, free from distraction and a multiple verification approach enhances accurate reconstruction of the victim's most recently documented antemortem dental condition.

The administrative team is composed of the dentist in charge of the dental section and a dental registrar or records custodian. The dental section leader has supervisory responsibility for all aspects of the dental operation and reports to the person with overall jurisdictional responsibility for the identification, which is usually the medical examiner. It is the dental section leader who reviews all suggested dental identifications and determines the degree of certainty in that process. It is also the responsibility of the section leader to maintain good communication of information with the other sections through daily briefings and conversely, to convey learned information back to his or her subordinates in the dental section. The dental registrar serves exclusively as the administrator of records. All antemortem and post mortem dental records are maintained under his or her custody.

The registrar is responsible for duplication of all dental records provided to other sources.

The records comparison and identification team evolves late in the course of the identification process from reassigned members of the post mortem and antemortem teams as they complete their previous respective tasks. The dental section leader is, *ex officio*, the final participant in the records comparison and identification process. In a mass disaster involving 25-50 victims, computerized comparison of records may be desirable, however manual comparison of antemortem to post mortem charts can still be easily accomplished. The AFIP antemortem and post mortem dental charts are designed so that when placed adjacent to the other, a mirror image is formed. This allows easy comparison of either charted symbols or written descriptors of the condition of all teeth. Separation of records by specific categories such as gender, primary dentition of a child, distinguishing dental characteristic such as 32 unrestored teeth, evidence of root canal therapy or fixed prosthesis prior to comparison can further facilitate the identification process. When record comparison of greater than 50 victims is performed, computer assistance significantly reduces the time required for comparison.

The computer program utilized by the AFIP team is Computer Assisted Post Mortem Identification developed by Colonel Lewis Lorton while serving at the U. S. Army Institute of Dental Research. Conditions such as an unrestored tooth, surface tooth restored by surface involved, and missing teeth are compared in the antemortem and post mortem data files. As programmed, the computer will analyze all records in each file and rank the most likely antemortem and post mortem match based on the highest number of similarities or the least dissimilarities between the antemortem and post mortem states. Verification of the suggested computer generated matches is then accomplished by review of charts and radiographs by the dentists.

The military dental services assigned to AFIP strongly advocate comparison of antemortem and post mortem radiographs in addition to dental charts whenever possible. Like fingerprints, dental radiographs are objective evidence and provide numerous points for comparison. Some of the potential characteristics for comparison include: shape of coronal restorations, presence of intermediate bases and pins, crown and root morphology, pulp chamber morphology and root canal filling, level of the alveolar bone, thickness of the periodontal ligament space, bone trabecular pattern, foramen, tubercles and sinuses, pathologic conditions, diastemas, malpositioning of teeth, missing or unerupted teeth. A single tooth as evidenced by antemortem and post mortem radiographs, if sufficiently unique, may provide numerous concordant points of comparison and effect a posi-

tive dental identification. Each case must be evaluated individually however based on the skill and experience of the dentist comparing and no firm rule applies to a prescribed number of concordant features which effect a positive match. When lack of radiographic evidence precludes such a comparison, charting alone may be utilized. It has been suggested that no fewer than 15 compared teeth must be in complete agreement as to their condition, with no other unresolved discrepancies, before charting alone should serve as a basis for positive dental identification.

When records comparison suggests that a match is possible or that no match can be made, a dental identification summary report is completed. This report, together with the antemortem and post mortem records which serve as the basis for this conclusion are reviewed by the dental section leader for accuracy. The dental section leader determines the degree of certainty of the dental identification. Although some have advocated up to five different degrees of identification certainty, military dentists employ merely three conditions; either antemortem/post mortem findings result in a positive identification with absolute certainty, the findings are consistent to support an identification but not to a degree allowing absolute certainty, or the findings do not support the making of an identification.

In some cases dentistry, as may other sections of the identification team, contribute to a presumptive identification by exclusion. An example of this situation might be found when it could be documented that only seven females are known to have been aboard an aircraft which crashed leaving no survivors. Six of the seven females are positively identified with absolute certainty by the dental section. A seventh, autopsy proven, anatomic female remains was recovered in a decapitated state. No dentition could be found for comparison however, by dental exclusion of all other possible victims, identification could be established.

The use of microdot information might be of considerable value in the identification of civilians, especially young children and adolescents who, by virtue of fluoridation and other preventive techniques, exhibit no restorations. In the military setting, this technology is presently not being utilized as medicolegal issues and lack of standards preclude its employment.

This discussion has centered on the methods employed by military dentists at AFIP in responding to mass disaster situations. The question might be legitimately posed, "how can this help me, as a member of the civilian dental community if a mass disaster occurs in my area?" The answer is clear. Civilian dentists can prepare, just as do their military counterparts. Dental societies can develop a disaster plan and train at the local level. Individual practitioners can document their records

as if those records might someday become the sole means of identifying their patient. This includes identification of all removable prosthesis with patient name and/or social security number. Those involved in dental school education can move as the military dental services have done, to incorporate forensic dentistry into the core curriculum of postdoctoral dental education and provide training at the undergraduate level as well.

The primary responsibility of the military dentist is to maintain the combat soldier, sailor or airman in a state of health which allows him to perform his mission. Hopefully there will never again be a time when our armed forces are lost in conflict, but part of our responsibility to that fighting force is to ensure them with the certain knowledge that every effort will be made to honor their sacrifice and assist their families by providing an identified body over which to mourn.

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# COMPUTER ASSISTED POST MORTEM IDENTIFICATION via DENTAL AND OTHER CHARACTERISTICS

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The site of a disaster in which many fatalities have occurred is a hectic environment. Accurate identification of the remains of deceased victims is of foremost importance to the forensic scientists at the site. High energy disasters such as bombings, airline crashes, etc., which are often accompanied by massive destruction and fire, may result in the destruction of identifying characteristics such as facial features, fingerprints and identification (ID) tags. The forensic examiners must then rely on dental characteristics as a "hard fingerprint" for identification of the victims.

Identification is important for a number of reasons. A positive identification is required to allow probate of the deceased's will and to collect insurance. On a psychological basis, lack of a positive identification can lead the family into false hopes that their loved one is still alive, thereby preventing them from getting on with their lives. Malpractice suits can arise from misidentification or a lack of identification. In a military situation, it may be critical to verify the death of a soldier who had access to sensitive information to ensure that the information is not compromised. For military manpower assessments, it is necessary to accurately identify the dead in order to sufficiently replace soldiers lost to units.

## METHODS OF IDENTIFICATION

The accepted legal methods of identification are visual/facial characteristics, fingerprints, and dental characteristics. Identification via DNA typing may also be accepted. In addition, personal effects, medical information, and unusual or distinctive body marks or devices may be used to assist in the identification.

Dental characteristics are commonly used because of their survivability and diversity. In high impact disasters, facial features and fingerprints are often destroyed. However, the teeth usually survive even the most destructive of disasters, allowing them to be used for identification. Dental characteristics are also diverse. Every adult has 32 teeth that may be present or absent. Any tooth can have up to five restored surfaces; the restorations can be of a variety of materials (gold, silver amalgam, plastic-like composites, etc.). In addition, tooth

size, shape, and orientation vary significantly between individuals. This considerable amount of dental diversity provides a large number of possible dental combinations that confers unique dental characteristics upon each individual. Therefore, the survivability and diversity makes dental characteristics ideal for identification purposes.

Experience gained by military forensic teams during a number of mass disasters has resulted in streamlined procedures for the identification of postmortem remains using dental characteristics. The dental identification process now involves a series of coordinated steps that are orderly and systematic. The steps are as follows:

- Step 1: Antemortem dental records are solicited and received from treating dentists. These records are often difficult to obtain. In the case of the military, the dental records have been destroyed during the disaster.
- Step 2: The antemortem dental records are examined by a dental forensic team.
- Step 3: The information in the antemortem dental records is then transferred to a standard antemortem dental form.
- Step 4: The postmortem remains are prepared and examined.
- Step 5: The dental remains are radiographed.
- Step 6: The dental remains are charted onto a standard postmortem dental form.
- Step 7: The antemortem and postmortem dental forms are then manually compared to find matches. This is a very time consuming step that requires a significant level of skill.
- Step 8: The matches are then validated with the radiographs to verify the match and make a positive identification based upon dental characteristics.

The flow of information therefore involves the gathering of information, comparison of data, and verification of the identification. This approach requires great skill and can be very labor and time intensive in a mass disaster situation due to the massive amounts of data involved. The result is a very costly endeavor that can take many days to complete.

## COMPUTER ASSISTED POSTMORTEM IDENTIFICATION

Computers are ideal instruments for the manipulation of large amounts of data. They process information rapidly with great accuracy and consistency and results can be retrieved with ease. Computers also provide better security. The result is a rapid and accurate manipulation of data with reduced costs. Dental data is ideal for computer manipulation as it is exact, constant at any point in time, and objective. Computers are therefore ideal for fast and accurate comparisons of dental data.

The United States Army Institute of Dental Research, under the direction of Lewis Lorton, COL, U. S. Army (retired), has developed the Computer Assisted PostMortem Identification (CAPMI) program, a computer software program which compares antemortem dental data to postmortem dental data. This program directs forensic examiners toward the most likely matches of antemortem records to postmortem remains (Step 7 just mentioned) so the examiners can rapidly proceed with a positive identification via radiographs. It precludes the need for a manual comparison of the records by forensic examiners, thereby saving time and expense. CAPMI saves time by being extremely fast and efficient: it compares and sorts 1200-5000 records per second on most IBM compatible computers. It will run on any MS-DOS computer (including laptop computer), any type of monitor, any type of printer and requires only 640K random access memory (RAM).

CAPMI is a menu based program that can be used with a minimal knowledge of the DOS operating system and minimal experience with computers. Separate antemortem and postmortem database files are created by entering data to the appropriate file. Data entry is performed by keyboard input or optical mark read forms. In the future, touch screen entry or voice entry may be available.

The following general data is included:

Last Name	Birth Date
First Name	Race
Middle Initial	Blood Type
Social Security Number	Eye Color
Weight (lbs)	Hair Color
Height (inches)	Examination Date
Sex	Post
Rank	Unit

Map grid coordinates may also be entered.

Tooth data include:

Missing Tooth	Unerrupted Tooth
Cavity on a Tooth	Anomalous Condition
Mesial Restoration	Occlusal Restoration
Distal Restoration	Facial Restoration

Lingual Restoration	Full Coverage Crown
Amalgam Restoration	Gold/Cast Metal Rest.
Nonmetallic Restoration	Ceramic or Acrylic/ Metal
Porcelain Jacket	Stainless Steel Crown
Crown	3/4 Crown
Temporary Restoration	Root Canal Treated
Pontic	Tooth
Deciduous Tooth	Removable Partial
Denture	
Virgin Tooth	

The following marks/devices may also be entered:

Colostomy	Pacemaker
Circumcision	Right Eye
I.U.D	Torus
Left Eye	Tracheotomy
Orthodontic Appliance	Scar (Burn)
Amputee	Scar (Surgical)
Birthmark	Scar (Trauma)
Dialysis Conn.	Surgical Clip
Deformity	Surgical Screw/Pin
Fracture	Surgical Plate
Isotope Insert	Surgical Wire
Joint Replacement	Tumor
Keloid	Tattoo
Maxillofacial Appl.	

The marks/devices may be entered with the following locations:

Head	Genitals	L Fingers
Face	R Shoulder	R Leg
Intraoral	R Arm	R Foot
Neck	R Hand	R Toes
Chest	R Fingers	L Leg
Abdomen	L Shoulder	L Foot
Back	L Arm	L Toes
Buttock	L Hand	L Toes

Help screens are available to provide the correct codes for each characteristic.

After the antemortem and postmortem data is entered, the dental information can be compared by using the Comparison Function. This function compares one or more records from one file (antemortem or postmortem) to all the records in the other file (postmortem or antemortem). It can compare and sort 1200-5000 records per second, depending upon the type of IBM compatible computer in use. It then produces a list of most likely matches, sorted in order of the most likely match to the least likely match. This list is based upon three methods of comparison: Match, Mismatch, and Possible. A Match occurs when the antemortem and postmortem dental data are exactly the same. A Mismatch occurs when the antemortem dental condition is different from the post-

mortem dental condition and it could not have evolved into the postmortem dental condition (Example: an antemortem tooth with three restored surfaces could not have two restored surfaces in the postmortem state). A Possible occurs when the antemortem dental condition is different from the postmortem dental condition but it could have evolved into this condition (Example: an antemortem tooth with two restored surfaces could have three restored surfaces in the postmortem state if unrecorded dental treatment had been performed). CAPMI sorts the comparison results and makes the most likely identities list, prioritizing by the number of Matches, Mismatches, or Possibles for each record-to-record comparison. The list can be viewed on the computer screen or printed. It is then used by the dental forensic team to assist in making the final identity. Therefore, CAPMI does not make the identification; it merely provides a list of most likely identities for use by the forensic team. This list precludes the need for an extensive manual comparison of many antemortem to postmortem dental records. The final positive identification is made by the team members after viewing the dental radiographs or other evidence.

CAPMI also has a Search Function. This function is used to find exact matches to a specific characteristic or group of characteristics. The search can be performed with dental data, nondental data (height, race, blood type, marks/devices, etc.), or grid coordinates. For example, if an antemortem medical record indicated an individual had a prosthetic hip on the right side, the postmortem data file could be searched for all records with an entry for a prosthetic hip on the right side. A list of all records containing the searched characteristics is viewed on the computer screen or is printed.

### ACCURACY AND USES OF CAPMI

In a study of 7,030 U. S. Army males with a mean age of 24 years (Lorton et al. 1986), the average individual had seven dental characteristics. For individuals with four or more characteristics, 93% had no other person with the same characteristics. For individuals with seven dental characteristics, the correct match was at the top of the most likely identities list 95% of the time. A correct match was found within the first ten records 100% of the time. Data entry errors affect the results; however, even with a 40% error rate, the correct match was in the top 20 records 95% of the time. In another study using 578 records (Lorton and Langley 1986), the correct match was at the top of the list 86% of the time.

CAPMI has been used successfully in mass disasters. In the 1985 Gander, Newfoundland crash, all 256 victims were identified; 67% of the identifications involved dental information facilitated by CAPMI. In the

Iowa Incident, all 47 victims were identified. CAPMI placed the correct individual at the top of the most likely identities list in all cases.

CAPMI is currently being used by the Army's Central Identification Laboratory in Hawaii in the identification of Vietnam-era remains, Graves Registration companies of the U. S. Army, the Armed Forces Medical Examiner's Office, and over 200 federal, state, county and international forensic/mass disaster agencies.

### FUTURE OF CAPMI

A pilot study is currently being conducted by the United States Army Institute of Dental Research to determine the feasibility of establishing a preexisting dental antemortem CAPMI database for Army soldiers. CAPMI antemortem dental data would be stored in a central location for Army personnel. In the event of a disaster, the antemortem data would be retrieved and sent to the processing station for use in the identification procedure. This Computer Assisted PostMortem Identification System (CAPMIS) would save time and expense and would increase accuracy by avoiding a search for antemortem dental records and onsite antemortem data input. As soon as postmortem information is entered into the system, a comparison could be run to produce a most likely identities list.

Programming in CAPMI is ongoing. The file structure is being rewritten to make it user customizable. In the future, virtual memory will be provided to allow use of an unlimited number of records in a file. A graphical interface is also planned.

### SUMMARY

CAPMI is a computer software program that assists in the identification of postmortem remains after mass disaster situations. It compares antemortem to postmortem dental and other characteristics and produces a most likely identities list. This list is then used by the forensic team to assist in the final identification process. The list does not make an identification; it minimizes the number of records that must be compared manually by the team, thus decreasing the time and cost involved in the effort. It has been shown to be highly accurate in laboratory testing and in actual disaster situations.

Copies of CAPMI may be obtained free of charge by writing to:

Commander  
U. S. Army Institute of Dental Research  
Walter Reed Army Medical Center  
ATTN: SGRD-UDR-E (CAPMI Support)  
Washington, DC 20307-5300  
AV 923-4881,4883  
comm.(301)677-4881,4883

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- Lorton, L., Cornwell, K., Langley, W. H. and Friedman, R. (1986). Computer Assisted Postmortem Identification. Medical Bulletin of the U. S. Army, Europe 43:31-35.
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# UNITED STATES ARMY CENTRAL IDENTIFICATION LABORATORY — HAWAII

*Brion C. Smith*

U. S. Army Central Identification Laboratory  
Fort Shafter, Hawaii

## MISSION AND ORGANIZATION

The U. S. Army Central Identification Laboratory, Hawaii (CILHI), is the only organization in the U. S. military that is solely responsible for the search, recovery and identification of service members killed or listed as missing.

The mission of the CILHI is to:

- Conduct search and recovery operations in the Pacific for World War II, Korean War and Vietnam War dead;
- Process remains and establish identities through the use of anthropological, odontological and other sophisticated scientific techniques;
- Accumulate and catalogue information on American and allied personnel listed as missing in action or declared dead but body not recovered;
- Provide worldwide emergency support to the Army Mortuary Affairs Program and, as required, to the Departments of the Navy and Air Force, for search, recovery and identification of remains of service members killed or missing in current operations;
- Perform humanitarian missions as directed.

The Central Identification Laboratory is a field operating element of the Casualty and Memorial Affairs Operations Center of the U. S. Army Total Personnel Command, Alexandria, Virginia.

The laboratory employs more than 40 military and Department of the Army civilians who are organized into three sections: Search and Recovery, Casualty Data Analysis and the Laboratory. Those sections are supported by the command elements which includes the office of the commander, unit supply, training and operations. The military and civilian staff of CILHI represents a wide range of training, education and experience. The majority of the military personnel are experienced Graves Registration Specialists with extensive training in map reading, search and recovery operations, archeological excavation techniques, records management and data processing. Other critical specialty areas within CILHI include mortuary affairs, logistics management and photography. The majority of the civilian scientific

staff have advanced degrees, primarily doctorates, and are members of professional associations, such as the American Academy of Forensic Sciences and the Mid-Pacific Association of Forensic Scientists. Some staff members are board-certified in their forensic specialty. Many of the staff have years of experience in Southeast Asia and have participated in the recovery and identification of thousands of casualties of aircraft crashes, multiple-death incidents and major battles such as the Tet Offensive and Khe Sanh.

## HISTORY

Throughout U. S. history, those killed in war have been recovered and interred to the best of the government's ability at the time. Some efforts to identify and return the dead can be traced back as far as the Seminole Wars of the 1840's. However, it was in the Civil War that the government assumed an obligation to identify and bury war dead in registered graves. This was possible through the aid of large numbers of citizen volunteer soldiers. Through their efforts, mortuary records were collected by posts and various units, and forwarded to the Adjutant General. In addition, complete records were maintained for soldiers who died in hospitals.

However, it is true that many men who fell in battle were interred where they fell with little attempt at identification. The Spanish-American War marked a major development of policy when remains were disinterred from their burial sites in Cuba, casketed, and returned to the U. S. for permanent burial.

A Graves Registration Service was introduced during World War I to recover and identify war dead. Congress authorized a return of remains program following the precedent established after the Spanish-American War.

During World War II, Congress again authorized a return of remains program and made the Secretary of the Army responsible for the program. Congress set a time limit of five years after the war for final resolution of the issue. Remains were processed by several Army identification laboratories which were dissolved in 1951.

A central identification laboratory was established in Japan during the Korean War to process United Nations Forces war dead. The laboratory remained in Japan

until it was dissolved in 1956. Some of the laboratory personnel remained in Japan and later provided assistance in identifying those killed during the Vietnam War.

During the war in Southeast Asia, the two U. S. Army mortuaries in Vietnam identified all service members. The immediate predecessor of CILHI was the U. S. Army Central Identification Laboratory, Thailand (CIL-THAI). It was established in March, 1973 at Camp Samae San, Thailand, following the withdrawal of U. S. forces from Vietnam and the closing of the Army mortuaries. Working with the South Vietnamese government until its fall in 1975, CIL-THAI was responsible for the search, recovery and identification of remains of U. S. service members killed in Southeast Asia only.

In May 1976, CIL-THAI was relocated to Honolulu, Hawaii and renamed CILHI. The organization's mission was expanded to include identification of service members killed in Korea and World War II, as well as those killed in current operations. Since 1976, the CILHI staff has assisted in the identification of casualties from several recent incidents to include: the bombing of the Marine Corps barracks in Beirut, Lebanon in 1983; the Arrow Air crash in Gander, Newfoundland in 1985; the USS Stark missile attack in the Persian Gulf in 1987, and the explosion aboard the USS Iowa in 1989.

### SEARCH AND RECOVERY SECTION

Before the identification process can begin, the remains of service members must be returned to the U. S. government. From Southeast Asia, remains have been received primarily through official repatriations, whereby a foreign government recovers the remains and returns them to U. S. custody. Remains are also returned through other sources such as refugees or recovery operations conducted by U. S. military organizations in allied countries. Additionally, CILHI conducts search and recovery operations with the cooperation of foreign governments.

CILHI has three fully qualified search and recovery teams which conduct thorough area searches and excavations of crash and burial sites to recover remains and personal effects. Through the use of detailed grid searches and other excavation techniques, the teams gather vital material and information from aircraft crash sites that are used in the identification process.

Most recently, search and recovery operations have been conducted in cooperation with the governments of the Socialist Republic of Vietnam, the Lao People's Democratic Republic, Papua New Guinea, the Republic of Korea, the Republic of the Philippines, the Solomon Islands and Malaysia.

During one mission to Papua New Guinea, a CILHI team located and identified a World War II aircraft

which had crashed in 1944. The search team worked for a week in the dense jungle to recover remains and personal effects from the crash site. Specialists in the laboratory later were able to establish the identities of all personnel aboard the aircraft and return their remains to the next of kin nearly 40 years after their loss. This case later became the subject of a book by Pulitzer Prize winner Susan Sheehan titled "A Missing Plane".

### LABORATORY SECTION

After CILHI receives the remains, the physical anthropologist and the forensic odontologist attempt to establish individual identities, using standard recognized forensic techniques and procedures.

Since remains received at the CILHI are often commingled, the first task of the laboratory staff is to segregate them, when possible, into separate individuals.

After segregating the remains, the anthropologists and odontologist examine them to determine all dental and anthropological data that can be obtained. They document their findings onto a series of charts, forms and special narratives and thoroughly radiograph and photograph all evidence. The skilled scientific staff can determine numerous individual characteristics through examination of skeletal remains. Frequently, age, race, sex, muscularity, handedness, and height, can be determined. Indications of injuries the person may have sustained or abnormalities that may have existed while the person was alive are also critical findings that may lead to an identification.

If dentition is received with the remains, the forensic odontologist examines the teeth to document restorations or unusual characteristics. For Southeast Asian cases, the odontologist's findings are entered into the Computer Assisted Post Mortem Identification (CAPMI) system, a computer program that has stored within its data base the antemortem dental records of the U.S. servicemen whose remains are listed as unrecovered. The CAPMI system compares the characteristics of the recovered dentition against the data base and generates a list of the most likely candidates for a match. The odontologist physically checks the dental records of the individuals listed by the CAPMI system with the actual remains and postmortem X-rays to try to establish an identity.

State-of-the-art computers, microscopes and radiographic equipment are among the items used by the anthropologists and odontologist in the identification process. The staff photographer operates a photo lab which also aids the scientists in their analysis and documentation of the skeletal remains.

Even with all the technology available and their many years of experience, the scientific staff is not

without its limitations. They can estimate the physical characteristics of a person and establish scientific probabilities, but they must have a "closed" population against which they can compare the physical data to establish an identification.

### **CASUALTY DATA ANALYSIS SECTION**

The casualty data analysts collect and maintain personnel, medical and dental files on U. S. service members whose remains have not been recovered. The number of unrecovered service members from all three wars make this a monumental task. For instance, the casualty analysts maintain records on the approximately 2,300 who have not been recovered from Southeast Asia as well as all who died and were recovered in the Vietnam War. The section also collects records and information on the more than 8,000 personnel from the Korean War and the nearly 79,000 from World War II whose remains have not been recovered.

While the scientific staff examines the remains, the casualty data analysts research all records with similar names, locations or dates that could be associated with the case. If remains have been recovered from an identified crash site, the records of the people who were manifested on that specific aircraft are reviewed to extract physical data that could assist in the comparison.

If, however, the remains have been returned through a repatriation, the source, whether a government or an individual, often provides a presumed name, probable date of death, and general location of recovery. Using this information, the data analysts determine which unaccounted for serviceman's loss scenario best matches the information provided by the source. That individual's last known location is plotted by computer, and all other incidents within a specified radius are drawn in for comparison. The files of all unaccounted for servicemen whose last known locations fall within the circle are screened by the analysts. The medical, dental and biographical information compiled on each individual by the analysts is then compared by the anthropologists and odontologist with the biological data they obtained from the remains. If a favorable comparison is not possible, the records search is expanded until a match can be made or all reasonable possibilities are exhausted. Only

then, is CILHI ready to make a recommendation based on its findings. Throughout the identification process, the staff can consult or request the assistance of several specialized agencies such as Tripler Army Medical Center, the Armed Forces Institute of Pathology, the Federal Bureau of Investigation, the Smithsonian Institution and the Naval Investigative Service. CILHI has obtained assistance from recognized leaders in many forensic specialties. The laboratory maintains a viable professional relationship, based on mutual assistance, with Medical Examiners and law enforcement officials in the mainland and Hawaii.

### **REVIEW PROCESS FOR IDENTIFICATION**

CILHI's recommendation for identification is forwarded to the Chief, Armed Services Graves Registration Office, who presents the case to board certified forensic consultants for their review. After the consultants review the case and concur with the recommendation, it is sent to the Service to which the deceased was assigned. The Service representative then notifies the primary next of kin of the recommended identification and reviews the entire case file with them. The family can choose to have the case reviewed by an independent expert of their own choice. If the family's expert differs with CILHI's recommendation, the case file and the comments of the family's expert are returned to the Army's forensic consultants for further evaluation. The family may also submit additional information to the Armed Forces Identification Review Board (AFIRB) for consideration in the review process. The AFIRB is a board of senior officers with one voting member from the Departments of the Army, Navy and Air Force who are responsible for reviewing all information submitted with the recommendation for identification. If the case concerns a Marine, the Navy may designate a Marine Corps representative as its member. The AFIRB is the final approving authority for each recommendation. It bases its decision on the preponderance of all relevant facts and circumstances surrounding the case. After the AFIRB approves an identification, the case is forwarded to the appropriate Service Secretary who is responsible for returning the remains to the family and for their final disposition.

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## FBI DISASTER SQUAD OPERATIONS AND NECESSARY PRE-PLANNING

*Robert J. Hazen*

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Washington, D. C.

In December 1989, the FBI Disaster Squad responded to a request from the Armed Forces Institute of Pathology, Washington, D. C., and traveled to Dover Air Force Base, Dover, Delaware, to render assistance in identifying the casualties of "Operation Just Cause," the military action in Panama. Nineteen of the 23 casualties were identified by fingerprints. This was the 163rd disaster in which the FBI had provided free humanitarian assistance to the citizens of the United States. During the past 50 years, the FBI Disaster Squad has identified over 3,500 disaster victims by fingerprints, palm prints and footprints.

### HISTORY

In August 1940, a scheduled airliner crashed near Lovettsville, Virginia, killing 25 persons, including two FBI employees. For humanitarian reasons, then FBI Director J. Edgar Hoover promptly dispatched a disaster team from the FBI Identification Division to the crash site to identify the bodies of the FBI employees. Initially, they found a grisly and confused scene. Only a few victims had been found and the identification efforts were stifled by confusion and disorder. The FBI experts ultimately took charge of the overall task and eventually



Figure 1. Photograph of the FBI Disaster Squad

all bodies were located and identified. From this baptism by fire, the FBI Disaster Squad came into being. During the past 50 years, the FBI Disaster Squad has responded to many different types of disasters, including airline crashes, shipwrecks, fires, hurricanes, floods, bus accidents, train accidents, mining accidents, bombings, explosions, hijackings, a mass murder-suicide and a volcanic eruption.

The FBI Disaster Squad is composed of special agents and highly specialized latent fingerprint identification experts assigned to the FBI Identification Division at FBI Headquarters. They are sent to the scene of a disaster in teams to conduct post-mortem fingerprint examinations. A photograph of the FBI Disaster Squad appears in Figure 1.

Worldwide assistance is available if the disaster victims are United States citizens. The FBI Disaster Squad has previously provided foreign disaster assistance in the following geographical locations around the world; France, Belgium, Italy, Canada, Venezuela, British West Indies, Tahiti, Indonesia, Greece, Canary Islands, Poland, Lebanon, Malta, Burma, Ethiopia, and Honduras.

### AUTHORITY

Title 28, Code of Federal Regulations, authorizes the Director of the FBI to provide humanitarian aid during disasters, subject to the general supervision of the Attorney General.

### Investigative Jurisdiction

The investigative jurisdiction of the FBI Disaster Squad is provided by Federal legislation enacted by the U. S. Congress. These acts are:

*Federal Aviation Agency Act, 1958:* Whereby it is a Federal crime to destroy or attempt to destroy a carrier involved in transportation of passengers and their property in interstate commerce.

An atrocious act which clearly illustrates this type of crime is the Jack Gilbert Graham case. A United Airlines flight left Denver, Colorado, in November of 1955. A short time later, over Longmont, Colorado, the plane exploded in midair, killing all 44 persons aboard. Graham had placed a bomb in his mother's luggage in order that he might collect the life insurance on her life and, in doing so, killed all the passengers on board the plane. The FBI reassembled the plane sufficiently so as to note a dynamite residue in the cargo compartment area, which indicated that an explosion had taken place. The investigation centered on Graham because of the substantial amount of life insurance he had taken out on his mother's life. A search of his residence located all the implements for making a bomb, such as was used to

blow up the plane. Confronted with the evidence, he ultimately confessed to what he had done. The irony of this case is that he never could have collected the money anyway. For the policy to have been valid, it was necessary that it be countersigned by his mother, and she had not done so. In January 1957, Graham was executed in the Canyon City, Colorado, gas chamber for this crime. Figure 2, an exhibit on the tour route at FBI Headquarters, Washington, D. C., dramatically illustrates this tragic event.

*Comprehensive Crime Control Act, 1984:* Whereby it is a Federal crime to engage in hostage taking of American citizens during an act of terrorism.

*Omnibus Diplomatic Security and Anti-Terrorism Act, 1986:* Whereby it is a Federal Crime to murder an American citizen outside the U. S. during an act of terrorism.

A tragic disaster which illustrates these two violations occurred in November 1985, when Egypt Air Flight 648 was hijacked by terrorists and forced to land in Malta. One American citizen was brutally murdered and her body was thrown down the steps leading from the plane. Several days later, Egyptian commandos assaulted the plane in order to rescue the passengers. In the exchange of grenades and gunfire, 59 of the 97 passengers and three of the terrorists were killed. The FBI Disaster Squad assisted the Maltese authorities in identifying the deceased and then conducted a latent print examination of the aircraft. On a window in the pilot's cabin, they developed and identified a latent fingerprint as that of the sole surviving hijacker, one Omar Marzuki. This evidence was turned over to the Maltese authorities who used it during the prosecution of Marzuki. Figure 3 shows Egypt Air Flight 648 on the ground at the Malta Airport. Figure 4 shows the interior of the plane after the exchange of grenades and gunfire.

### SOURCES OF ANTE-MORTEM FINGERPRINT RECORDS

Within the FBI Identification Division, over 189 million sets of fingerprints are on file. The names of disaster victims are quickly and efficiently searched through the FBI Identification Division indices. The ante-mortem fingerprint records from the FBI Identification Division files are then taken to the disaster scene by the FBI Disaster Squad. Often the ante-mortem fingerprint records can be compared with the post-mortem fingerprints of the disaster victims and the identifications can be effected quickly at the disaster scene.

However, for this search to be conducted in an efficient manner, it is imperative that the local authorities quickly provide as much identifying data as possible on the disaster victims, that is, complete name, sex, race, date and place of birth, as well as social security and military service numbers, if known.



Figure 2. Exhibit on the FBI Headquarters tour route which dramatically illustrates this tragic event.

A large percentage of applicant fingerprint cards submitted to the FBI for search are returned to the local contributors. Accordingly, a search of state, county and city law enforcement files may locate additional ante-mortem fingerprint records.

Inked fingerprints are also recorded on the driver's licenses or driver's license applications for California, Colorado, Hawaii and Nevada. Hospital birth records also could be a source for the fingerprints of the mother or footprints of the infant.

If ante-mortem fingerprint records cannot be found for a victim, it may be necessary to examine objects from the victim's residence for latent prints (that is, documentary materials such as letters, school papers, address books, check registers, etc.). Any latent prints developed will then be compared with the post-mortem prints recorded from the body. This can often be a tedious and time-consuming process. However, every effort must be made to positively identify the disaster victim. Figure 5 depicts latent fingerprints developed on an address book found on the body of a disaster victim are compared with the ante-mortem fingerprint record, and the identification is effected.

## DISASTER PRE-PLANNING

It is absolutely necessary that local jurisdictions develop a pre-existing disaster plan which can be quickly and effectively implemented if a disaster should occur. The conception of a thorough and efficient disaster plan



Figure 3. Egypt Air Flight 648 on the ground at the Malta Airport.



Figure 4. The interior of the plane (Egypt Air Flight 648) after the exchange of grenades and gunfire.

requires the participation and cooperation of all area law enforcement agencies, fire departments, rescue squads, hospitals, the U. S. Military and volunteer service agencies such as the American Red Cross, Salvation Army and ministerial associations.

#### **Command Structure**

One of the most important decisions to be made is who will ultimately be in charge of the overall disaster operation. The medical examiner or coroner, of course, have jurisdiction over the examination, identification and release of the bodies. Determination of leadership responsibilities is particularly important in co-jurisdictional areas and in areas where jurisdiction is not clearly delineated. The chain of command must be positively established and the areas of responsibility of each participant clearly defined. The best time for this to be established is in the pre-planning.

#### **Disaster Site and Morgue Pass System**

A bright, easily recognized identification pass for accessibility to the disaster recovery site and the morgue

is most important. Experience has shown that unless access to these sites is restricted, they will be inundated with curiosity seekers and bereaved relatives. Such unnecessary intrusions will interfere with the orderly processing of the deceased. A bright, easily recognized identification pass will significantly contribute to the

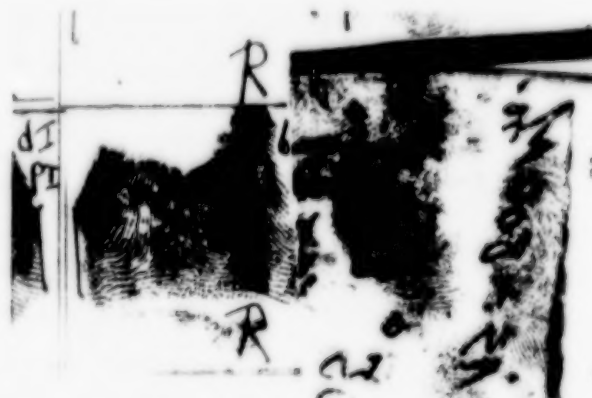


Figure 5. Latent fingerprints developed on an address book (on the left) found on the body of a disaster victim are compared with the antemortem fingerprint record (on the right) and the identification is effected.

control of unnecessary and unauthorized persons in this sensitive area. The same pass should be used for all agencies involved. If each law enforcement agency involved has a different pass, it will cause unnecessary confusion at the sites.

### **Morgue Facilities**

The U. S. Military maintains two large mass casualty facilities, one at Travis Air Force Base, near Sacramento, California, and the other at Dover Air Force Base, Dover, Delaware. However, most jurisdictions do not have morgue facilities in which large numbers of bodies may be properly maintained and processed; accordingly, arrangements to use available existing facilities as temporary morgues must be made. Gymnasiums, auditoriums, armories, meat packing plants, airplane hangars and refrigerated vans have been successfully used for this purpose.

In selecting the morgue facility, the following factors must be considered:

- 1 — Space. Sufficient for temporary storage of the victims and necessary processing equipment.
- 2 — Security. Strict control of access to the area must be maintained. Unless access to the morgue is restricted, the area will be inundated with unauthorized visitors which will interfere with the orderly, methodical examination of the victims. When the activities at the morgue are stopped at the conclusion of each day, it will be necessary to have law enforcement officers provide morgue security.
- 3 — Communication facilities. If not available, the necessary equipment must be installed as soon as possible.
- 4 — Electrical provisions. Ample for lighting, electrical outlets and ventilation.
- 5 — Accessibility to disaster site.
- 6 — Assembly point. An area physically removed from the examination area must be established for friends and relatives of the victims.
- 7 — Viewing space. A convenient separate, private and secure area should be established for relatives or friends to use when viewing the deceased or when viewing personal effects for purposes of identification.

### **Special Equipment**

Disaster recovery operations may require special equipment for rescue and transport. This could include

helicopters, bulldozers, boats and dredges, chain saws and body bags. The U. S. Military which should be involved in your pre-planning is an excellent source for this type of assistance.

### **Responsibility of Medical Examiners or Coroners**

The medical examiner or coroner has jurisdiction over the examination, identification and release of the bodies.

The FBI certifies all identifications effected by fingerprints, palm prints or footprints and will present testimony in any subsequent litigation regarding the identification effected.

Local authorities must be prepared to resist religious or political pressure for the premature release of the bodies prior to a positive identification being effected. Historically, releasing bodies based on tentative eyewitness identifications has resulted in unnecessary erroneous identifications.

### **MEDIA RELATIONS**

A proper media relations program will insure the public of receiving important, current and accurate information regarding disaster operations. For successful media relations, the following guidelines should be adhered to:

- 1 — One person is designated the media information officer. All information must be released through this officer. Inquiries to other members of the disaster team must be tactfully referred to this individual.
- 2 — Do not release any information on disaster victims until next of kin have been notified.
- 3 — Be fair in dealing with the media. Give equal credit to all law enforcement agencies involved in disaster operations and make sure that all members of the media receive the information at relatively the same time.
- 4 — Identifiable faces of the victims should not appear in photographic or television coverage.

### **Arrival at the Disaster Scene**

Upon arriving at the disaster scene, initially all efforts should be directed towards rescuing and rendering assistance to any survivors.

An excellent example of this was a fire that occurred at a large supper club. When the fire departments

first arrived at the scene, there were still people alive in the facility. So they were simultaneously fighting the fire and rescuing as many people as possible from the burning building.

The next important responsibility at the disaster scene is that the perimeters of the disaster must be established and the scene protected as soon as possible. Curiosity seekers and scavengers who are invariably attracted to such catastrophes must be prevented from penetrating the disaster scene. This very situation occurred at the supper club fire, when some of the deceased disaster victims from the fire were initially laid out on a nearby lawn and immediately scavengers began systematically looting the bodies of wallets, watches, rings, etc.

When providing security over a large geographical area, it may be necessary to ask for assistance from the state police or the National Guard. Stringent curfew regulations or martial law allowing only police, National Guard and emergency workers in these areas after dark may be warranted.

When the disaster scene has been secured, the bodies should be numbered chronologically as they are found at the scene. A tag reflecting this number is placed on the foot of the victim and on the body bag. When the bodies are received at the morgue, personal effects (jewelry, wallets, clothing) should be placed in a separate container reflecting the body number. These personal ef-

fects should then be remanded to the custody of the medical examiner or coroner. Later they may assist in establishing positive identity of the disaster victim.

### **REQUEST FOR FBI DISASTER SQUAD ASSISTANCE**

Any request for assistance should be directed to the nearest FBI Resident Agency or Field Office in your area. The request can also be made by calling the office of the Assistant Director, FBI Identification Division (202) 324-5401 during normal workday hours. During nights, weekends and holidays, the FBI Identification Division may be contacted by calling (202) 324-3362.

### **CONCLUSION**

No single disaster action plan is all encompassing. Modifications of any plan may be necessary, depending upon the circumstances of the particular disaster. It is also known that disasters will create complex problems and a severe shortage of personnel for law enforcement agencies. However, many of the pitfalls and shortcomings that develop during the law enforcement response to these tragedies can be avoided by thoughtful pre-planning.

# THE POTENTIAL OF DNA TYPING IN DISASTER SITUATIONS

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There are numerous features that can be exploited for the identification of an individual in a forensic context. These features can be acquired or congenital, and include physical appearance, wearing apparel, dentition, fingerprints, skeletal structure, and genetic pattern. Among these features, only an individual's genetic pattern cannot be altered or counterfeited. Moreover, only genetic patterns can be used to link an individual with close blood relatives. When routine identification measures fail to provide sufficient information to make an identification, laboratories will turn to tests that rely on genetic information. The genetic tests that have been the mainstays of forensic identifications for years are based on structural differences in proteins or carbohydrates that are genetically inherited and thus can differ among individuals (see review by Sensabaugh 1982). The major drawbacks to the use of these protein and carbohydrate genetic markers are their structural instability once tissue becomes non-living and a low number of genetically distinct types in the population. Thus, traditional genetic markers have a modest power to enable resolution among individuals. Clearly the field of forensic biology was ripe for the discovery of genetic factors that would improve our ability to distinguish among individuals. Such discoveries were made in the last decade and demonstrated that the fundamental genetic material itself, deoxyribonucleic acid (DNA), exhibited considerable variation among individuals. How the variability at the level of DNA can be exploited in the forensic laboratory is the subject of this document, part of which has been taken from an earlier publication (Baechtel 1988).

## FUNDAMENTALS OF DNA STRUCTURE

Deoxyribonucleic acid (DNA) is an organic substance found primarily in the chromosomes that are structures within the nuclei of cells. The DNA within any chromosome is composed of two strands, wound about each other in a helical fashion. Each DNA strand is a polymer, composed of molecules, called nucleotides. Four different nucleotides are found in DNA, deoxyadenosine monophosphate (A), thymidine monophosphate (T), deoxycytidine monophosphate (C) and deoxyguanosine monophosphate (G). It is more convenient for the following discussions to refer to the nucleotides solely by the letters, A, C, G and T.

A single strand of chromosomal DNA is a chain composed of hundreds of thousands of these letters. Because the order of the four letters can vary from one position to the next in the chain, an almost infinite variety of letter sequences can be developed. Chromosomal DNA, as was stated, is composed of two strands, and these two strands associate with each other in a certain way that is governed by the chemical properties of the letters in each strand. The letter A in one strand will associate only with the letter T in the other strand. Likewise, the letter C in one strand will only associate with G in the other strand. A short sequence of double-stranded chromosomal DNA might look like this:

- A-C-G-T-A-A-A-A-G-T-T-C-C-  
- T-G-C-A-T-T-T-T-C-A-A-G-G-

## CHROMOSOMES AND HEREDITY

The nucleus of every cell in the human body contains 23 pairs of chromosomes for a total of 46. The exceptions are the sperm cell and the female ovum (egg cell), which contain only 23, unpaired, chromosomes each. When a sperm cell fertilizes an ovum, the cell that results (zygote) will possess 46 chromosomes, 23 from the father and 23 from the mother. Since the chromosomes are the cellular repositories of DNA, one-half of the DNA in a person is of paternal origin and one-half is of maternal origin.

## REPETITIVE SEQUENCES IN DNA

Many of the letter sequences in chromosomal DNA code for the production of proteins that are required for the development and maintenance of life. These functional sequences are called genes, and always are inherited in pairs. One member of a gene pair is received from each parent.

All the letter sequences in DNA do not code for the production of proteins. Within the letter sequences that intervene between the protein coding regions can be found sequences of letters that are repeated multiple times. These non-coding regions are inherited in the same manner as are the protein-coding regions of DNA. An imaginary repeat sequence in DNA is illustrated in Figure 1. The two double-stranded sections of DNA

-G-A-T- A-C-A-T-C-A-T-C-A-T-C-A-T- C-A-T-G-G- <u>A-T</u> - A-T-G-G-	Strand 1
-C-T- A-T- G-T- A-G-T- A-G-T- A-G-T- A-G-T- A-G-T- A-C-C- T-A-T- A-C-C-	
-G-A-T- A-C-A-T-C-A-T- G-G-A-T- A-T- G-G-A-A-G-T-T- T- A-C-G-	Strand 2
-C-T- A-T- G-T- A-G-T- A-G-T- A-C-C- T- A-T- A-C-C- T-T-C- A-A-A-T-G-C-	

Figure 1. Two double-stranded sections of DNA (Strands 1 and 2) represent the multiple repeat regions from each member of a chromosomal pair. The DNA from one chromosome contains six repeats of the sequence -C-A-T- (Strand 1); and the DNA from its partner chromosome (Strand 2) contains three repeats of the same sequence.

shown represent the multiple repeat regions from each member of a chromosomal pair. The DNA from one chromosome contains six repeats of the sequence -C-A-T-; and the DNA from its partner chromosome contains three repeats of the same sequence. The six repeat sequence was inherited from one parent and the three repeat sequence from the individual's other parent.

### RESTRICTION FRAGMENT LENGTH POLYMORPHISMS

The presence in DNA of multiple repeats of letter sequences is the foundation on which rests one of the methods by which body fluid and tissue specimens can be genetically characterized. The characterization is based on a determination of the lengths of the repeated sequences harbored in specific areas of an individual's DNA. The length of a section of DNA that contains the repeated sequences is a direct function of the number of times a sequence is repeated. To determine the length of the repeat sequence present in each of the chromosomes, the repeating units must be cut out of the DNA strands and separated on the basis of their length. The repeat sequences are removed from the DNA strands through the use of special enzymes called restriction endonucleases. These enzymes, which are obtained from bacteria, will cut through both strands of DNA only when a certain recognition sequence of DNA letters is present. These recognition sequences are distributed randomly throughout all of an individual's DNA. For the strands of DNA shown in Figure 1, assume that an endonuclease is available that will cut DNA wherever the sequence -G-A-T- occurs. Because the -G-A-T- sequence appears on both sides of the repeated sequence, these sequences will be freed in their entirety from the long strands of DNA upon enzymatic digestion. The repeated sequences that have been released by restriction endonuclease digestion (Figure 2) are termed restriction fragments. Length differences in the DNA that can be detected following restriction digestion are termed restriction fragment length polymorphisms (RFLP). Studies by a number of scientists (Wyman and White 1980; Jeffreys *et al.* 1985; Nakamura *et al.* 1987) led to the use of these areas of DNA for distinguishing among individuals.

Before the fragment lengths can be measured, the fragments must be separated from one another on the basis of their size. The separation of DNA fragments by size is accomplished by a technique known as electrophoresis. The restriction-digested DNA is placed into a gel that acts like a molecular sieve when the DNA fragments are pulled through it by an electrical field. During electrophoresis, the smaller fragments will move farther through the gel than can the larger fragments.

The behavior of the two restriction fragments that contain the C-A-T sequences during electrophoresis is shown in Figure 3. The greater length of the larger fragment causes it to pass more slowly through the sieving gel than the smaller fragment. After about 16-20 hours of electrophoresis, the shorter fragment will have moved farther down the gel than the longer fragment.

Once the fragments of DNA have been physically separated, the remaining steps in the analysis are directed at an identification of the sizes of the fragments. The size identification steps cannot be done readily if the DNA fragments remain in the separation gel, so they are transferred to a nylon membrane in exactly the same array as they existed in the gel. This transfer is known as Southern blotting (Southern 1975) and is named for the developer of the technique. During the transfer process, each of the DNA fragments is chemically separated into its two component complementary strands.

After transfer to the nylon membrane, the fragment locations on the membrane are established using a DNA probe. A DNA probe is a short sequence that is complementary to the region of DNA that one wishes to detect. In the case of the C-A-T sequences, the probe must be composed of the letters G-T-A because this letter sequence is the complement of C-A-T. DNA probes can be tagged with radioactivity or other indicator molecule to facilitate their detection later in the analysis.

The membrane, with its array of DNA fragments, is immersed overnight in a solution that contains the radioactive probe of sequence G-T-A. During this time, the probe molecules will match up with the areas of the DNA fragments that contain the complementary sequence of letters and form a double stranded molecule. For the two fragments shown in Figure 3, there will be six probe molecules bound to the large fragment and three probe

-A-C-A-T-C-A-T-C-A-T-C-A-T-C-A-T-G-  
 -T-G-T-A-G-T-A-G-T-A-G-T-A-G-T-A-G-T-A-C-

-A-C-A-T-C-A-T-C-A-T-G-  
 -T-G-T-A-G-T-A-G-T-A-C-

Figure 2. Repeated sequences released by restriction endonuclease digestion.

(-)

-A-C-A-T-C-A-T-C-A-T-C-A-T-C-A-T-C-A-T-  
 -T-G-T-A-G-T-A-G-T-A-G-T-A-G-T-A-G-T-A-

-A-C-A-T-C-A-T-C-A-T-  
 -T-G-T-A-G-T-A-G-T-A-

(+)

Figure 3. Two restriction fragments that contain the C-A-T sequences during electrophoresis is shown. The larger fragment passes more slowly through the sieving gel than the smaller fragment. Thus, the shorter fragment moves farther down the gel than the longer fragment.

molecules bound to the smaller fragment. After this procedure takes place, which is called hybridization, the membrane is washed thoroughly to remove any unbound probe.

The final step is directed at determining which areas of the membrane contain radioactivity. The membrane is covered with a sheet of unexposed X-ray film and stored from one to seven days at a very low temperature. During this storage, the radioactive particles expose the X-ray film at the exact location of the DNA fragments that have hybridized with the probe molecules. When the X-ray film is developed, the locations of the fragments that have hybridized with the probe are seen as lines on the film (Figure 4).

The actual size of each of the fragments is calculated by reference to standards of DNA of known size that are run in parallel with the test specimens. The determination of fragment sizes can be carried out by computer assisted image analysis techniques.

The fragment pattern shown in Figure 4 is illustrative of the result when a single locus DNA probe is used. Single locus probes are used to detect repetitive sequences that occur at a single location in the DNA from one pair of chromosomes. The usual number of bands that are seen on the X-ray film is two (one band is derived from each chromosome). However the same size fragment can be inherited from each parent, in which case only a single band would be seen.

The number of different sized repetitive sequences that occur in the human population that are detected by a given single locus probe is limited, and varies with the DNA probe being used as well as the restriction endonu-

lease used to cut the DNA strands. One of the DNA probes in use by the FBI Laboratory enables the detection of more than 50 different sized repetitive sequences in the population. Because at most, one individual can possess only two different sized sequences in his/her

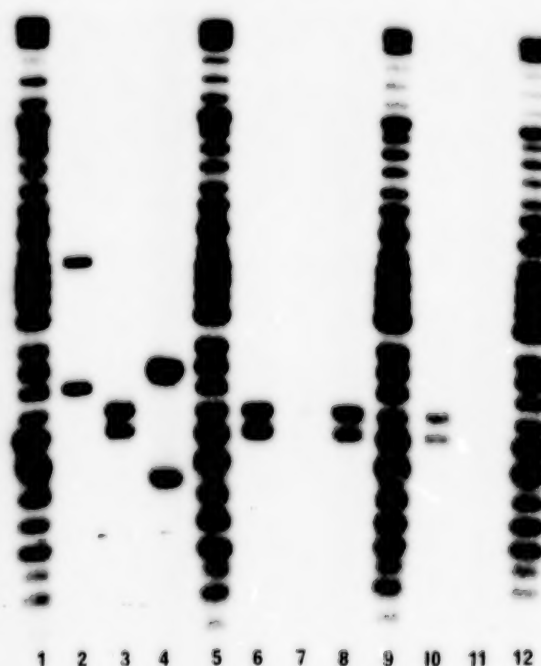


Figure 4. Autoradiogram of DNA fragments from human DNA specimens. Lanes 1, 5, 9 and 12 contain DNA fragments of known size that are used as references. Lanes 3, 4, 6, 7, 8 and 10 contain human DNA. Lane 11 is empty. Lanes 3, 6, 7, 8 and 10 contain DNA from the same individual.

DNA (when using a given probe), the number of different combinations of size sequences that can be present is large. As the number of combinations becomes large, the chance of two unrelated individuals having the same two fragment sizes becomes correspondingly small. Although the use of a solitary single locus probe can reduce considerably the number of potential contributors of a tissue specimen, additional DNA probes must be applied to the resolved fragments to enable a more comprehensive individualization of the specimen source (Budowle *et al.* 1990).

To genetically characterize a specimen to the extent that it can be stated that only one person on earth has the same profile, requires the application of several single locus DNA probes, each of which recognizes a different, and genetically unrelated, series of repeated DNA sequences.

### DNA SEQUENCE POLYMORPHISMS

While RFLP analysis relies on differences in DNA fragment lengths among individuals, another category of DNA analysis exploits differences in the sequence code of DNA letters within and between individuals. One of these test procedures is directed at differences that lie in an area of the DNA termed HLA-DQ $\alpha$ . Because the number of HLA-DQ $\alpha$  types that occur in the population is not large, the degree to which a DNA specimen can be genetically characterized is considerably less than that achievable by RFLP analysis. Because the differences in the HLA-DQ antigens are due to different arrangements of a small number of DNA letters rather than due to different lengths of a repeat sequence, an electrophoretic separation of DNA is unnecessary. Instead, DNA specimens are tested against a battery of DNA probes that represent each of the HLA-DQ $\alpha$  sequences that occur in the population (Saiki and Erlich 1988).

In reality HLA-DQ $\alpha$  testing employs two separate techniques in one testing procedure. Before DNA can be tested using DQ $\alpha$  probes, it must be subjected to an amplification procedure called polymerase chain reaction.

### POLYMERASE CHAIN REACTION

The polymerase chain reaction (PCR) technique (Saiki *et al.* 1985, 1988) repetitively reproduces copies of a subanalytical quantity of a DNA sequence until the quantity of DNA copies is at a sufficient level for testing.

The mechanism by which PCR effects the duplication of the DNA specimen is composed of three steps. For example, assume that the following sequence of DNA is to be increased in quantity by the PCR procedure.

-A-T-T-C-G-G-C-A-C-T-C-C-G-A-A-  
-T-A-A-G-C-C-G-T-G-A-G-G-C-T-T-

First, the two strands of DNA must be separated by raising the temperature to about 95°C.

-A-T-T-C-G-G-C-A-C-T-C-C-G-A-A-  
-T-A-A-G-C-C-G-T-G-A-G-G-C-T-T-

Second, short pieces of laboratory synthesized DNA, called primers, are permitted to attach to each DNA strand as the temperature is lowered. The sequence of DNA letters that immediately precede the region that is to be amplified must be known in order to synthesize the primers.

-A-T-T-C-G-G-C-A-C-T-C-C-G-A-A-  
-T-A-A-G-  
  
-T-A-A-G-C-C-G-T-G-A-G-G-C-T-T-  
-C-G-A-A-

The third step is called primer elongation and is effected by DNA polymerase and the four letters (A, C, G, T) that compose DNA. The DNA polymerase will start at the end of the primer and, by using the four letters, synthesize complementary copies of each of the two strands.

-A-T-T-C-G-G-C-A-C-T-C-C-G-A-A-  
-T-A-A-G-C-G-T-G-A-G-G-C-T-T-  
  
-T-A-A-G-C-G-T-G-A-G-G-C-T-T-  
-A-T-T-C-G-G-C-A-C-T-C-C-G-A-A-

After the first round of synthesis has been completed, the temperature of the reaction is once again raised to 95°C to separate the DNA strands. Primers again attach to what are now four strands and the temperature reduced so that the DNA polymerase can reinitiate DNA synthesis starting at the primer sites. Each cycle of PCR doubles the quantity of DNA that was present at the beginning of the cycle. Thus, the PCR procedure increases the quantity of DNA strands in an geometric manner (that is, 2, 4, 8, 16, 32, etc). After approximately 20–25 cycles, sufficient DNA should have been produced to enable the testing of the sample.

While PCR treatment of DNA specimens is obligatory for the use of probes to the HLA-DQ $\alpha$  region of DNA, its use is not confined exclusively to this application. In fact, methods are currently under development that utilize the PCR technique to amplify the regions of DNA that contain repeated sequences.

# APPLICATION OF CONTEMPORARY METHODS OF DNA ANALYSIS TO MASS DISASTER SITUATIONS

Both of the methods of DNA analysis described in the preceding sections are applicable to tissues and fluids recovered from mass disaster victims. Exposure of tissues and fluids to environmental adversities will diminish the quality of the DNA within those sources and can lead to failures of the test procedures to reveal any genetic information.

Regardless of the test procedure used to reveal genetic differences at the level of DNA, one cannot determine anything about the external appearance or health status of an individual through these approaches. These tests do not reveal that an individual had blue eyes or brown hair or diabetes or cancer. The only manner by which the results of DNA testing can be used to identify an individual is through comparison of the DNA profiling results with the profile results derived from either an exemplar specimen of DNA from the individual, or with profiles developed from DNA of close biological relatives. Because most persons have not set aside any of their blood or other tissues for reference purposes in the event they are the victim of a mass disaster, profiles of relatives must serve as reference profiles. Biological relatives who are closest genetically (that is, parents) to the disaster victim are best for these comparisons.

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# CLANDESTINE DRUG LABORATORY SAFETY

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The illegal and clandestine manufacturing of illicit substances presents a multitude of unique health and safety problems to law enforcement and forensic science personnel. In recent years, significant interest and attention had focused on issues and concerns related to the health and safety of field investigators. The seizure and field investigation of clandestine laboratories is no longer perceived or handled in a manner similar to other, more traditional, enforcement activities. Recognition of the serious toxicological, chemical and physical hazards associated with illegal chemical manufacturing has necessitated a new approach to such investigations. An evaluation of clandestine laboratory hazards, review of past injury and exposure incidents and promulgation of applicable regulations has prompted in the U. S. Drug Enforcement Administration (DEA) and numerous state and local law enforcement agencies to develop health and safety programs for this unique area of investigation.

## OVERVIEW

Recognized clandestine laboratory activity began in the U. S. during the 1960's. One of the earliest documented laboratory seizures (amphetamine) occurred in Santa Cruz, California in 1963. Illegal laboratory manufacturing of methamphetamines started in the early 1970's, and now represents approximately 80% of laboratories seized by DEA annually (McKinnon, R., personal communication). During the 1980's, a serious and dramatic increase in laboratory activity occurred in the U. S. DEA documented over a 340% increase in laboratory seizures from fiscal year 1980 (235 seizures), to 1988 (810 seizures). Geographic distributions documented in 1989 indicated that approximately 82% of all laboratories occurred in California, Oregon and Texas. By drug type, methamphetamine production represented approximately 82-85% of all clandestine laboratories investigated in the U. S. during the last several years. In addition to methamphetamine, other illicitly manufactured substance commonly documented in seizure statistics include phenyl-2-propanone (P2P), phencyclidine (PCP), amphetamines, LSD (lysergic acid diethylamide), MDA (3,4-methylenedioxymphetamine), MDMA (3,4-methylenedioxymethamphetamine). Approximately 15-20 types of clandestine laboratories (illicit substance and manufacturing method combinations) may be commonly

or occasionally encountered, encompassing the potential use of over 200 precursor, reagent, solvent and catalytic chemical materials.

The diversity of laboratory types, range of commonly used and substitute chemicals, required apparatus and equipment, and unique site conditions dynamically interact to produce myriad serious, often life-threatening, hazards to field investigative personnel. Historical and current experience has demonstrated that these hazards present a real and serious threat to field personnel safety. For example, prior to the inception of formalized clandestine laboratory health and safety programs in 1987, the Sacramento, California joint State Department of Justice (DOJ)/DEA task force experienced a 100% casualty rate for its agents and chemists. From the initiation of the task force, through 1986, virtually every member of that unit had experienced at least one incident of chemical exposure or other laboratory related injury (excluding suspect associated). An informal survey conducted by task force members of other task force and investigative units in California and neighboring states revealed similar experiences. The types of generic exposures and incidents that investigators have experienced include chemical inhalation, eye and skin exposures, site explosions and fires, glassware rupture, chemical container failure, compressed gas cylinder leads, chemical incompatibility reactions, etc. These situations are a result of the interaction of necessary field investigative activities, that is, site seizure, chemical inventory, sampling, evidence collection, site closure, etc., and the numerous and diverse hazards created as a result of illicit chemical manufacturing, that is, the use of hazardous chemicals and equipment in a clandestine and uncontrolled environment (Table 1). Field seizure and evidence collection at clandestine laboratory sites require investigative personnel to perform physically hazardous activities in chemically contaminated environments.

## LABORATORY HAZARDS

The chemical hazards presented at a laboratory site by virtue of the inherent physical and chemical properties of reagent and precursor substances is extensive. The most prevalent chemical hazard property omnipresent at virtually every laboratory is explosiveness/flammability. Numerous solvents and reagents including ethyl

**Table 1. CLANDESTINE LABORATORY HAZARDS SUMMARY**

Type	Hazards
Flammable Atmospheres	Fire, explosion, structural damage, container damage/failure
Sources of Ignition	Initiate fire, explosion or booby trap
Compressed Gas Cylinders	Generate flammable, explosive or toxic atmosphere; deflation, projectile
Reactions in Progress	Generate IDLH, toxic, or flammable atmosphere; source of ignition; incompatibility reaction, electrical hazard
Incompatible Chemicals	Generate heat, fire, explosion, toxic or flammable gases, pressure, etc; container damage, source of ignition
Unstable Container Storage	Spill, leak, mixing of incompatible chemicals, physical injury
Toxic Atmospheres	Acute chemical exposure
Oxygen Deficient Atmospheres	Asphyxiation
Confined Space Entry	Injury or death from flammable, oxygen deficient and/or toxic atmospheres
Damaged Containers	Container rupture or explosion; fire, leak, exposure
Electrical Hazards	Electrocution, burns, sources of ignition, booby-trap trigger
Heat Stress	Heat exhaustion, heat stroke, loss of attention, fatigue
Slip, Trip, Fall	Physical injury, container damage/leak, chemical exposure
Limited Egress	Delayed emergency evacuation, prolonged hazard exposure
Limited Work Area	Container/Apparatus upset, damage; spill, chemical exposure

ether, acetone, methanol, benzene, toluene, isopropyl alcohol, carbon disulfide and hydrogen gas are highly flammable and explosive. By category, solvents represent the single largest volume of chemical found in most laboratories. The second highest volume of chemical typically found at laboratories are corrosives, both inorganic acids and strong caustics. These materials are extremely corrosive to skin tissue and especially the eyes. Hydriodic, hydrochloric, acetic, perchloric, and nitric acids are universally associated with drug laboratory production, along with many alkaline materials including sodium hydroxide, sodium carbonate, ammonia gas and methylamine. Catalysts often used include magnesium turnings, sodium metal, lithium aluminum hydride and raney nickel. These substances are especially dangerous because they may be water reactive or pyrophoric and/or solvent reactive (depending on the chemical), presenting serious handling and incompatibility hazards. Compressed gases, including hydrogen chloride, hydrogen, and on rare occasions methylamine, are commonly found in laboratories. In addition to the chemical hazards related to the cylinder contents, the condition, misuse, and handling of compressed gas cylinders may result in rupture, explosion, fire and/or serious chemical exposures. Also, numerous chemical incompatibility hazards exist at laboratories (Table 2). For example, oxidizing chemicals including nitric acid, perchloric acid and bromine may be associated with some production methods and are highly incompatible with the organic solvents also used in production. Other incompatibility hazards include acids and cyanide salts, acids and caustics and chlorides and water. A final consideration is that almost all booby traps encountered in laboratory situations are chemical in nature (Table 3).

In addition to the inherent chemical property hazards, the diversity of toxicological hazards presented by chemicals used in controlled substance production are serious and significant. Virtually all chemicals found in laboratories may enter into the body, resulting in exposure to one or more target organs of the body. Although exposure alone does not automatically infer an adverse health effect, the potential for acute exposures to various chemicals resulting in dangerous dosages to the body is a reality.

Solvent and acid vapors, gases and some chemical aerosols may be inhaled directly into the respiratory system. In addition, approximately 25% of commonly found clandestine laboratory chemicals may be absorbed through the skin. Finally, accidental ingestion of chemicals may occur as a result of poor work practices or personal hygiene. Clandestine laboratory chemicals considered toxic to the respiratory system include upper respiratory irritants (acids and alkalines) and lower respiratory irritants (that is, phosphine, phosgene). Respiratory asphyxiants include some solvent vapors (that is, freon, chlorinated solvents, etc.), hydrogen and cyanide compounds which may react with acids to form hydrogen cyanide gas. Examples of laboratory chemicals which are toxic to the other visceral organs of the body (systemic toxins) are replete. Many of the solvents, especially chlorinated solvents, and metal catalysts are hepatic and/or nephritic toxins from which serious exposure may result in liver and/or kidney disfunction. In addition, most solvents and some metals are toxic to the central nervous system. Further, chemicals including benzene affect the hemopoietic (blood forming) tissues of the body. Both male and female reproductive organs are susceptible to damage from exposure to some sol-

**Table 2. CLANDESTINE LABORATORY INCOMPATIBILITY HAZARDS**

INCOMPATIBILITY		HAZARD	
Cyanide Salts Sodium cyanide Potassium cyanide	and	Acids	Hydrogen cyanide gas
Acids Hydrochloric Sulfuric Glacial acetic Hydriodic	and	Caustics Sodium hydroxide Calcium hydroxide	Violent reaction, toxic gas, heat, etc.
Water Reactive Metals Magnesium turnings Sodium Sodium borohydride Lithium aluminum hydride	and	Water	Fire and/or explosion
Air Reactive Metals Raney Nickel	and	Air	Ignites on contact with air
Organics (Solvents) Ethyl ether Alcohols Acetone Aromatics (Benzene, Toulene) etc.	and	Oxidizers Nitric Acid Mercuric Nitrate Perchloric acid	Fire explosion, heat, toxic gas, etc.
Catalysts Palladium black Lithium aluminum hydride Raney Nickel	and	Solvents Ethyl ether Alcohols Acetone	Fire and/or explosion  Aromatics
Chlorides Thionyl chloride Phosphorous trichloride Phosphorous pentachloride	and	Water	Forms strong acid vapors in air

CAUTION: This is not a complete list of all incompatibility hazards potentially associated with clandestine laboratory activities.

vents and metals found at laboratories including ethanol and lead acetate. In addition, many clandestine laboratory chemicals have been classified as carcinogenic and/or mutagenic. Examples including acetamide, carbon tetrachloride, perchloroethylene, chloroform, lead acetate, benzene and vinyl chloride. Some substances including intermediate chemicals, contaminants, and the controlled substances themselves often present unknown toxicological hazards by virtue of insufficient scientific data. Little is known about the long term health effects of exposure to the vast array of chemical intermediates potentially produced in manufacturing.

The toxicological hazard of the controlled substances must also be considered. For example, exposure to PCP, its precursors and analogues have occurred to a number of agents and officers. The drug is cumulative in nature and has an unknown active life. In at least one incident, a female officer who had been accidentally exposed to PCP during an investigation unknowingly exposed her

unborn child (Egger, B., personal communication). Other officers have reported symptoms of drunkenness, hyperactivity, lightheadedness, headaches, skin rashes, elevated heart rate, confusion, short term memory loss, aggressiveness and hallucinations after exposure to PCP during laboratory raids. Studies have verified the presence of PCP in blood and urine samples of people who live near PCP laboratories and of narcotics officers who have entered such laboratories (Aniline *et al.* 1980). By contrast, a narcotics agent investigating a seized LSD laboratory in Northern California in 1989 was exposed to an estimated 1,000 dosage units of LSD via accidental skin contact and absorption (Largent, D., personal communication).

Two other clandestinely manufactured drugs which create significant health and safety problems are the fentanyl compounds (synthetic heroin) and demerol analogues, MPPP desmethyprodine) and MPTP (1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine). In the case of the

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**Table 3. LABORATORY BOOBY TRAPS**

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The following types of booby-trap hazards have been encountered by law enforcement personnel at clandestine drug laboratory sites. (WARNING: This is not a complete list.)

1. Small foil balls containing a strong oxidizer, reactive metal and solvent. Extremely shock sensitive, unstable and explosive. Usually marble to golf ball in size.
  2. Light switches wired to flammable liquid containers, flash pans, booby-trapped light bulbs or other explosive devices.
  3. Refrigerator doors (and/or their internal light bulbs) wired to detonate a flammable liquid or explosive when opened.
  4. Mock video tape cassettes containing an internal explosive material designed to detonate when placed into a video player.
  5. CO<sub>2</sub> cartridges, gun barrels, steel pipes, dummy pineapple grenades, etc., filled with explosive material and connected to a detonation device.
  6. Hydrogen cyanide gas generator.
  7. Open flammable liquid adjacent to an incendiary device.
  8. Attack dogs and poisonous snakes.
  9. Monofilament trip lines connected to chemical or explosive booby traps and/or firearms.
- 

fentanyls, minute amounts as small as a grain of salt, can cause death. These compounds can be absorbed through the skin or mucous membranes. MPPP/MPTP laboratories also represent a serious threat and environmental hazard to both the public and narcotics officers since MPTP has been directly linked to Parkinson's Disease.

Lastly, many serious physical hazards also exist at laboratory sites. Though not as intuitively dangerous as the chemical hazards presented, many physical hazards may still result in serious, even life threatening, incidents. Many laboratory sites by virtue of the clandestine operation may be considered confined spaces requiring extreme caution and attention to safety procedures to ensure safe entry. The investigation of laboratories located in underground vaults, caves and abandoned mines has been documented, and is on the increase. The use of chemical protective clothing may cause the onset or aggravation of temperature stress upon the body, which if unchecked, may rapidly result in heat stress and heat stroke. Further, a recent trend in defendants burying laboratory waste ultimately results in soil excavation as part of field investigation. Entrance into unprotected excavations five feet or deeper can result in fatal collapses. Other examples of physical hazards include poor lighting, confined work locations, slip and trip hazards, limited egress, excessive materials handling, heavy lifting, electrocution from substandard electrical connections and equipment, fire damaged buildings, and handling damaged compressed gas cylinders.

## REGULATIONS

The presence and exposure to the various hazards posed by clandestine laboratory operations obligates compliance with applicable OSHA regulations to ensure personnel health and safety. By executive order, Federal agencies including the DEA must comply with Federal Occupational Safety and Health (OSHA) or equivalent regulations. State and local agencies in OSHA approved plan states must comply with state regulations which are equivalent to those promulgated by OSHA. Further, agencies in non-OSHA approved plan states must comply with U. S. Environmental Protection Agency (EPA) safety regulations mandated by Congress in 1984 to cover jurisdictions not regulated by OSHA in relation to OSHA's Hazardous Waste Operations and Emergency Response Standard (see following discussion). The congressional intent of OSHA when created by the Occupational Safety and Health Act of 1970, was to provide a safe and healthful working environment to all employees. Many of the regulations developed and enforced by OSHA, and contained in 29 CFR, delineate numerous procedures, rules, standards and requirements, which are directly applicable to clandestine laboratory working environments.

A prime example of OSHA regulatory applicability to laboratory activities involves the use of respirators. Although use of personal protective equipment to control exposures to chemical and physical hazards is a last choice, preceded by engineering and administrative controls, the practicality of clandestine laboratory field situations routinely calls for the use of protective clothing and respirators. Issuance of respiratory protective devices to agents and chemists mandates compliance with the requirements for respiratory protection (29 CFR 1910.134). The employer must have a written respiratory protection program, provide annual medical evaluations to determine individual fitness to wear a respirator, provide annual training in selection and use, conduct annual fit testing to document proper sizing, monitor work environments to determine proper equipment selection and control of hazards through equipment use, and provide proper maintenance, inspection and storage of equipment. Although compliance with this standard may be arduous, it is mandated if employees are exposed to concentrations of toxic airborne contaminants at a laboratory site in excess of OSHA specified Permissible Exposure Limits (PELs) and engineering controls are inadequate or not feasible to control exposure. An additional compliance area involves Hazard Communication (29 CFR 1910.1200). This standard promotes a safer work environment by requiring more and better information to field personnel regarding chemical hazards and proper chemical handling procedures.

Finally, with the passage of the Superfunds Amendments Reauthorization Act of 1986 (SARA), OSHA was directed by congress to develop and implement health and safety regulations applicable to hazardous waste operations. In response, OSHA issued the Hazardous Waste Operations and Emergency Response Standard (29 CFR 1910.120), the final rule of which became effective March 6, 1990. Section (q) of the standard applies to emergency response operations and requires that a safety program include initial, annual update an exit comprehensive medical examinations, 24 hour initial and annual update training for all field employees, and additional training for supervisors, written procedures governing the selection and use of chemical protective clothing and equipment, hazard assessment and site characterization procedures, contingencies for addressing site emergencies, air monitoring, engineering methods for the control of hazards and several other components. The DEA determined that clandestine laboratory field operations may be considered essentially equivalent to chemical emergency response operations as defined by the standard and acted to develop and implement a health and safety program as specified by the regulation.

### **SAFETY PROGRAMS**

In response to the need to protect the safety of personnel in the field and to concurrently comply with OSHA regulations, DEA has developed and initiated a clandestine laboratory safety program applicable to both agent and forensic chemist activities. The program was developed through the input of agent and chemist personnel and with the assistance of OSHA, EPA, the National Institute of Occupational Safety and Health (NIOSH) and industry consultants. Recognizing the uniqueness of laboratory investigation work, requiring personnel to perform forensic and law enforcement activities in hazardous and chemically contaminated environments, the DEA borrowed and adapted for its safety program development many procedures and requirements commonly employed for hazardous waste emergency and clean-up operations. The program includes extensive initial and periodic medical examinations and monitoring, 40 hours of initial certification and periodic update training, detailed standard operating procedures specifying hazard assessment, safety and chemical handling requirements and responsibilities, selection and issuance of personal protective clothing and equipment and methods for the proper handling of hazardous materials and waste seized and/or disposed of following laboratory seizure. State and local law enforcement agencies have followed the DEA actions and have initiated similar health and safety programs for clandestine laboratory enforcement teams.

Paramount to all aspects of the DEA's clandestine laboratory safety program is the inclusion and active participation of all field personnel including forensic chemists and other criminologists. The health and safety of all personnel involved in an investigation must be secured. Chemists have equal opportunity for exposure and injury, and therefore should receive the same benefits of a safety program. All field personnel should therefore included in medical monitoring, training, and equipment issuance. The technical knowledge and experience inherent to forensic chemistry provides a vital and irrevocable element to hazard identification and assessment, hazard control, field risk management, and public and environmental protection. Recognizing this premise, the DEA has included both forensic chemists and agents in all aspects of their clandestine laboratory safety program. A similar trend is prevalent in state and local safety programs.

### **CONCLUSION**

Since the initiation of the DEA's formalized clandestine laboratory safety program in 1987, agent and forensic chemist safety has been dramatically elevated. Even though the trend in laboratory seizures is still increasing, the ability of field personnel to safely secure, assess and process each new laboratory crime scene is now afforded via extensive training, implementation of standard operating procedures and use of specially issued personal safety equipment. With the development and implementation of such programs, clandestine laboratory crime scene is now becoming a routine component of illicit substance manufacturing investigations.

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# PHYSICAL AND BIOLOGICAL HAZARDS IN DISASTER MATTERS AND CRIME SCENE RECONSTRUCTION

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Disasters occur without warning and range from airplane crashes to natural disasters such as floods, earthquakes and tornadoes. For law enforcement and the communities involved to properly manage these disasters prior planning is essential.

Along with planning for evacuation of the sick and injured, restoring utilities, prevention of looting and general law enforcement, another aspect which is important for those involved in these type activities is safety for personnel at the scene.

This paper will examine some aspects of safety at the scene of a disaster.

## GENERAL PRECAUTIONS

No person at the scene of a disaster where deceased bodies, body fluids, or body parts are present should be allowed to eat, drink, smoke or apply makeup. The best personal protection device for personnel at the disaster is latex gloves, which will be discussed in more detail in another section. They should be changed if torn or soiled, and always removed prior to leaving the scene, even if temporarily. While wearing gloves, avoid handling personal items such as expensive pens and pencils. Hands should always be washed after gloves are removed, even if the gloves appear to be intact. Gloves and other disposable items should be disposed of properly.

## ELECTRICAL SAFETY

At scenes of disasters, whether an airplane crash which has severed power lines, or tornadoes and high winds which have blown them down, extreme caution must be taken with power lines, especially when water is present. Injuries from electricity may be minor or fatal, depending on the voltage and amperage received by a person. Fatal injuries are usually caused by either brain damage, which can cause respiratory arrest, or by fibrillation of the heart. Therefore, before conducting any activity at the scene of a disaster, it is imperative that knowledgeable utility company employees have cleared the scene of dangerous electrical wires.

## EXPLOSIVES

A disaster may involve the explosion of a bomb, either in an aircraft, automobile or a building. Although

not frequent, secondary explosive devices may also be present and it is essential that prior to the normal activities at the scene, with the exception of the evacuation of the injured, that qualified explosives experts clear the area prior to the entry of disaster squad personnel. While conducting the scene, any device which could possibly be explosive should never be touched. The area should be evacuated and proper explosives disposal personnel notified to remove the device.

## HAZARDS OF INFECTIOUS DISEASES

When traveling to an area of a disaster, especially natural ones, the possibility of insect, air or water borne infectious diseases may exist.

When disasters have disrupted the sanitary treatment of drinking and waste water, several human pathogens can contaminate the water. Therefore, bottled water or water which has been purified by chemical treatment must be used for human consumption. One of the most common compounds used to purify water is halazone (parasulfone dichloramidobenzoic acid). A halazone concentration of 4 to 8 mg/L disinfects even fairly hard water in approximately 30 minutes. Another compound which is effective is chlorimide. Both are available in tablet form (Wistreich and Lechtman 1984).

Some examples of water-borne pathogens include several species of *Salmonella* bacteria which can cause typhoid fever, *Shigella* bacteria which can cause severe gastrointestinal disorders, and *Vibrio cholerae*, the causative organism of cholera. In addition, a few species of parasitic protozoans and viruses, such as hepatitis A and polio viruses may also be present. One protozoan, *Entamoeba histolytica* which causes amoebic dysentery is particularly resistant to chlorine disinfectants. Iodine preparations are available against this organism. Boiling water for 15 to 20 minutes is also a very effective way to treat drinking water, although not always practical.

Insect transmission of pathogenic organisms can occur almost anywhere in the world. Insects are capable of transmitting a wide variety of infectious diseases including meningitis, yellow fever, malaria, encephalitis and Lyme disease. Therefore, personnel working in areas where these diseases are endemic should take appropriate precautions, particularly against mosquitoes and

ticks. These precautions include the use of insect repellants, nets for sleeping, vaccinations, chemoprophylaxis and careful, daily inspections for ticks. It should be noted that insects are not capable of transmitting AIDS. This has been confirmed by worldwide research projects (Miike 1987).

The most effective insect repellants are those which contain N,N diethylmetatoluamide (DEET). Diethylmetatoluamide is found in many commercially available insect repellants in varying concentrations. However, it should be noted that some people have an adverse reaction to DEET including potentially serious toxic encephalopathy.

Malaria presents a special problem in certain parts of the world since there is no vaccine against the disease. Malaria transmission occurs in large areas of Central and South America, Hispaniola, sub-Saharan Africa, the Indian Subcontinent, Southeast Asia, the Middle East, and Oceania. The risk of acquiring the disease varies markedly from area to area.

Malaria in humans is caused by one of four protozoan species of the genus *Plasmodium* and all are transmitted by the bite of an infected female *Anopheles* mosquito. The disease is characterized by fever and "flu-like" symptoms which may occur at intervals. Malaria may be associated with anemia and jaundice and certain species of the protozoan may cause kidney failure, coma and death.

Several chemoprophylactic drugs such as chloroquine, Mefloquine, Doxycycline, Proguanil and Primaquine, are currently available against the malarial organism and Pyrimethamine-sulfadoxine for presumptive treatment. However, none should be taken, nor a combination of any without first consulting a physician (CDC 1990a).

Yellow fever presently occurs only in Africa and South America. It is a viral disease transmitted by *Aedes aegypti* mosquitoes which breed in stagnant water. At one time it was believed this disease had been eliminated worldwide due to the elimination of the *Aedes* mosquito. However, periodic reinfestations of some countries have occurred in recent years in Brazil, Bolivia, Ecuador, Panama, Venezuela, Colombia, the Guyanas and West Africa. Fortunately, a vaccine is available against the disease. Yellow fever vaccine is a live, attenuated virus preparation which is safe and effective (CDC 1990b).

Meningitis is a term which refers to an inflammation of the meninges of the brain and spinal cord. This disease can be caused by numerous microorganisms, however, the most dangerous is that from the bacteria *Neisseria meningitidis*. This bacteria is capable of causing the death of a human faster than any other infectious agent. Death of patients has been reported to occur in less than 2 hours after the appearance of the first symp-

toms. Meningococcal meningitis has presented a serious problem in Africa since World War II. The disease has been found in an area extending across Africa from the shores of the Atlantic Ocean to those of the Red Sea, and north of the Equator to south of the Sahara. This region is referred to as the "meningitis belt" (Wistreich and Lechtman 1984). However, the disease is also rarely found in almost all countries. The mode of transmission of this disease is direct contact with another human who is infected. Because of the virulence of this disease, it is highly recommended that vaccination of disaster personnel be provided.

Lyme disease is now the most common arthropod-borne disease in the United States. In its earlier history, the manifestations were confined to the northeastern part of the United States; however, today it has spread to 43 states, throughout Europe, the Soviet Union, Japan, and other countries (CDC 1989b).

The deer tick *Ixodes dammini* is an intermediate host for the bacterium *Borrelia burgdorferi*, the causative agent of Lyme disease. This disease, which was named after the town in Connecticut where it was discovered, causes fever, fatigue, nerve damage, arthritis, and in rare cases heart problems and permanent joint disability if untreated. In some cases, a ring shaped rash will form around the bite (Weistreich and Lechtman 1984). Fortunately, it is treatable with broad spectrum antibiotics such as tetracycline. No vaccine against Lyme disease currently exists.

In late summer newly hatched tick larvae take their first blood meal from white-footed mice, some of which harbor the Lyme disease bacteria. In the following spring, the larvae molt into tick nymphs and again feed either on mice, deer or humans. This is probably where most of the cases of Lyme disease originate. It should be noted that these tick nymphs are very small — about the size of a sesame seed — hard to see and in some cases are difficult to feel on the skin.

The best preventive measure against Lyme disease is avoidance of the tick in the first place. Insect repellant containing DEET will help prevent ticks from biting, but not always. When conducting disaster matters in the summer, all personnel should carefully inspect themselves for any crawling or embedded ticks and any found removed promptly. Generally (but not always) a tick will require approximately 24 hours after attachment for the infectious anticoagulant to be injected. Ticks should be removed preferably with tweezers as close to the head as possible by pulling with a gentle, steady pressure. They should not be removed by heating and never squeezed. If any of the above symptoms appear after having been bitten by a tick, a physician should be consulted.

## VACCINATIONS

Personnel traveling to the scenes of disasters should inquire about the requirements for vaccinations in each respective country. This can be accomplished by consulting with the nearest representative of the World Health Organization or the appropriate embassy or consulate. The FBI Disaster Squad requires its members to be vaccinated against yellow fever, tetanus-diphtheria, typhoid fever, polio, meningitis and hepatitis B, and occasionally hepatitis A and cholera.

### HANDLING DECEASED PERSONS, BODY PARTS AND BODY FLUIDS

Personnel at disasters who handle bodies, body parts, or body fluids must follow the "Universal Precautions". This means that all bodies, body parts and body fluids must be assumed to be infected with HIV (the AIDS virus) and other blood-borne pathogens (CDC 1989a).

With respect to HIV (human immunodeficiency virus), hepatitis B, and other human viruses in deceased bodies, the author is not aware of any scientific research or publication dealing with the longevity of viruses in deceased persons. However, viruses are all strict obligate intracellular parasites and cannot survive in dead persons. Further, a search of the literature failed to disclose any instance of personnel in law enforcement or emergency services who have contracted a viral disease from the handling of deceased persons.

When a person dies, two natural processes begin, almost instantly to decay the body. The first is a process called "autolysis" which involves the activity of various intracellular enzymes that begin to break down body tissues and fluids. The second is putrefaction which involves the destruction of tissue produced by uncontrolled bacterial multiplication and fermentation. The microbial flora of the human body is normally kept in check by the immune system. When this system no longer functions, aerobic and anaerobic bacteria, particularly those of the intestinal and respiratory tracts, begin to multiply in great numbers causing massive destruction as well as the production of gases. The marbling effect seen in corpses is caused by hemolyzed blood reacting with hydrogen sulfide gas to produce a green/black color. Blood provides a channel for putrefying microorganisms and is an excellent medium for bacterial and fungal growth. In persons who are exsanguinated, the putrefying process is decreased, as well as bodies in extremely cold temperatures. Bodies which have been in water for long periods of time exhibit an "adipocere" appearance caused by the hydrolysis of subcutaneous fat to free fatty acids which then combine with calcium and ammonia to basically pro-

duce soap (Spitz and Fisher 1980). If a body is infested with maggots, the maggots also excrete enzymes which further dissolves tissue (Lord and Rodriguez 1989).

Bodies with traumatic injuries will decompose at even a faster rate. If anaerobic *Clostridia* bacteria are present in a wound, for example, complete petrification may occur in less than six hours.

It is this massive bacterial production in deceased persons which generally will not allow for parasitic viruses to grow. However, some of the bacteria in deceased and putrefying bodies are also harmful. Therefore, when handling the deceased, in any condition, appropriate precautions must be adhered to.

The *Clostridial* bacteria mentioned above includes those responsible for tetanus, gas gangrene and botulism. All of these bacteria produce spores which are analogous to seeds in a plant and which can survive virtually indefinitely in nature. For the spore to germinate, it requires a proper food source (a deceased human) and must reproduce without free oxygen. Therefore, when handling deceased bodies it is imperative that personnel wear latex gloves at all times to prevent either these bacteria or the spores from invading small cuts or injuries on the hands.

### HIV AND HEPATITIS B VIRUSES IN BLOOD AND OTHER BODY FLUIDS

Two studies conducted on HIV (in concentrated levels) determined that between 90% and 99% of the viruses were inactivated within several hours by drying but found that in liquids kept at room temperature the virus (again in concentrated levels) could survive at least 15 days (CDC 1987) (Resnick et al. 1986). Hepatitis B most probably can survive longer the HIV in both dried stains and in liquid blood.

### PRECAUTIONS AS THE SCENE

#### Latex gloves

It is recommended that disposable latex gloves be worn by all personnel when handling bodies, body parts, or body fluids. They are available in convenient containers, are ambidextrous, and are available in different sizes. They need not be sterile. Any time the gloves become heavily soiled or torn replace them immediately. Even if wearing gloves, hands should always be washed with soap after their use. In a situation where sharp objects are expected to be handled, such as sharp glass, metal fragments, etc., heavier latex gloves are recommended. It should be kept in mind that no latex glove will prevent a hypodermic needle from penetration (Bigbee 1989).

## Face and eye protection

In areas where there is a possibility of blood or other body fluids being splashed into the face or hands, it is recommended that face masks and eye protection be worn. In addition, if dried blood or other body fluids are being scraped, it is also recommended that face masks and eye protection be worn. An alternative to eye protection and face masks is the wearing of full face shields.

## Clothing Protection

It is recommended that when handling mutilated or bloody bodies, or when large amounts of body fluids are present that impervious gowns, coats or aprons be worn. Impervious shoe coverings are also available commercially.

## Hypodermic needles

Great caution should be used when searching clothing, luggage, or other objects for the presence of hypodermic needles and syringes. Intravenous drug users are also in the high risk category for AIDS, tuberculosis and hepatitis B. It is estimated by the U.S. Centers for Disease Control that an individual's chances of becoming infected with AIDS from a needle stick injury contaminated with HIV is one chance in 100–200 based on medical personnel studies. The injection of HIV infected blood from a needle and syringe is almost certain to transmit HIV. Therefore, when searching automobiles, or in domiciles, it is recommended that mirrors and flashlights be used to determine if needles are present prior to the insertion of the hands under or in any object.

## At autopsies or when amputating fingers from the deceased

The Centers for Disease Control recommends protective masks and eyewear (or face shields), laboratory coats, gloves, and waterproof aprons when performing or attending all autopsies.

## DISINFECTANTS

A wide variety of disinfectants are available and efficient for disinfecting the skin, equipment, and body fluids. One of the most efficient is a very common and inexpensive antiseptic; 70% isopropyl alcohol. This chemical may be used on the skin, on minor cuts, scrapes, and needle stick injuries. It should be applied and allowed to air dry. It can be purchased in a variety of containers including foil wrapped individual packets. The addition of iodine to the alcohol (tincture of iodine) greatly increases the disinfectant properties. Alcohol (nor

iodine) should ever be used in the eyes, mouth, or mucous membranes.

One of the best disinfectants for equipment, objects such as autopsy tables, laboratory benches, etc., are the halogen containing compounds including iodine and chlorine. Unfortunately, most compounds of chlorine are inactivated in the presence of organic material and some metallic catalysts. Therefore, if using chlorine compounds, the preparations should be made fresh at least weekly, and in highly contaminated areas, daily.

Hypochlorite solutions, for example, sodium hypochlorite (commercial chlorine bleach) are most commonly used as disinfectants and are relatively harmless to human tissue. They do, however, leave a residue that is irritating to the skin and mucous membranes.

Phenol containing compounds are also very effective disinfectants. However, they are irritating to the skin, and mucous membranes. One derivative of phenol is chlorhexidine, which, when combined with soap is a very effective skin disinfectant. If using any phenol compound it should be kept in mind that the substance may be mutagenic and/or tumorigenic since these effects have been seen in animal studies.

As previously mentioned, bacteria of the genus *Clostridia* may be found in dead and decaying bodies. These bacteria are anaerobes and cannot survive in high levels of oxygen. Hydrogen peroxide (3%) may be used as to clean and disinfect wounds contaminated with anaerobic bacteria since the peroxide degrades into water and oxygen in tissue (the typical foaming activity seen with peroxide).

## CONCLUSION

There are many hazards associated with conducting disaster matters. However, most of them can be overcome by using protective equipment, vaccination, and disinfectants but primarily by using common sense. Fortunately it is rare that individuals involved in mass disasters are injured or become ill. Along with proper pre-planning for disasters, pre-planning for safety aspects of the disaster are essential. Injured or infirm individuals will be of no assistance during a disaster and may very well be a liability.

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## STRESS MANAGEMENT: A MATTER OF PRIORITIES

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Let me begin by stating: "This job will never come first in my life." While at first this sounds rebellious and would appear to come from someone who is not committed to excellence in his/her job, that is simply not the case. Very often people go into a job forgetting that the job is to support one's family and the individual lifestyle one has chosen. While there are times when the job does not allow very much time for the family or personal time, this is the exception more often than not, not the rule. Human beings, according to the Spanish philosopher Ortega, are the only animals on the planet earth that are born into a state of total disorientation with their world. At some point in time they begin to make choices. Yes, we are the only animals on the planet Earth who can make choices in deciding what we become. Thus, as stated by many wise scholars and philosophers, the greatest difficulty in life is choice.

I would like to address the topic of prioritizing your life, to define what creates stress, and to suggest ways to eliminate the counterproductive affects of it. You will not eliminate stress from your life, but stress management can be learned. It is important to realize that good stress (eustress) and bad stress (distress) are not the same, but the body cannot tell the difference. The body reacts in the same manner in either case. This is known as the General Adaptation Syndrome.

Stress management should be made one of the most important things you do. There is nothing advantageous to having somebody say what a great employee you were if they are talking over your dead body; not unless of course, people are also remembering your wonderful personal qualities and dedication to your life and family. That is how serious it gets. I doubt that anyone has ever overheard a patient being rolled into an emergency room stating "Gee, I wish I had spent more time at the office!"

A survey conducted at the FBI Academy by the Institutional Research and Development Unit, asked law enforcement agencies throughout the United States to list, in order of importance, what they deemed to be the topics in which they needed training. The number one answer was training in how to handle personal stress. The inference is that law enforcement officials have been taught most of what they need to know to conduct their duties. The major topic which has been ignored is providing guidance in how they can integrate their jobs and their personal lives.

Regarding men, how much time do you spend talking to your children in the evenings, if they are still home; and if not, when they were? In one survey, reported by Dr. James Dobson, the average amount of time fathers spent communicating with their children was 37 seconds a day. If you think you can tell your children about what you believe in, or how you met their mom, or what you do for a living, or how much you really love and care for them in that amount of time, you are deceiving yourself. If that figure, 37 seconds is even close to accurate, then it is fair to say most men have their priorities way out of line. While children are taking the brunt of adult criticism regarding crime, drugs, and the like, we must remember that children do not need our criticism, they need models.

One of the best ways to reduce stress in your life is to improve the quality of your life outside work. Find something else to do. Struggle like I do: play golf. As Mark Twain once said, that little ball sure ruins a good walk. But it gets me away from phones, and I do not play with FBI agents. I do not want to say, "Boy, that was a nice shot," and have some guy say, "10-4." I want to get away from that stuff for a while. I need time for my family and time for myself.

Let me talk about a couple of myths in stress management. First is that all stress is bad. Well, all stress is not bad. There is good stress, like having a baby or getting married. This brings us to the term perception. Maybe you have seen this in a grocery store: a lost dog poster that says, "Lost dog: Ear bitten off, tail missing, leg broken. Answers to the name of Lucky."

Think about it. That dog is lucky; it ought to be dead. Maybe you are lucky. Maybe you are here for all the wrong reasons. Maybe you have had that chest shut down on you; maybe you have gone through your millionth Rolaid. If you had invested a little bit in relaxation, you might have bought some stock in the company and let other people take pills.

It is not the job of doctors to manage your stress; all they can do is try to repair you. It is not the FBI's job to manage my stress. It is in business to investigate federal crimes. It is not your company's job to manage your stress. Sure, it might have a place for you to go if you succumb to it, but the responsibility is yours. Once you allow someone else to take control over your stress management, then you become a loser. You must main-

tain control of your own health and accept responsibility for it.

Another myth is that stress should be avoided at all costs. You do not avoid stress. If stress is part of life, how are you going to avoid it? Where are you going to go? How are you going to hide? Another myth is that tranquilizers and drugs may be used to eliminate stress. Does this country sell drugs? We can talk all we want to about heroin and cocaine, but look at some of the prescription drugs being sold and the amounts they are being sold in. Shame on us. You are not eliminating stress; all you are doing is masking symptoms. This is a failure to face the problem.

Another myth is that to avoid stress a person should work as little as possible. Now would not you love for that to be true? Ever had a day with nothing to do? I do not want to be around you. You complain when you are busy, and you are miserable when you are not. That is why there are only two tragedies in life. One of them is getting everything you have always wanted; the other is not getting it.

Another myth: Stress affects only adults. No. You can take your stress home with you and affect everybody around you.

Here is another myth: People at the top of their professions are most likely to suffer heart attacks due to job stress. Sorry, you do not have that excuse. People at the top of their professions are no more likely than anyone else to suffer heart attacks related to stress. You are a human being. You might have a few unique stressors placed on you, but you basically face what everyone else in the world faces.

I hope you will look inside your own life and say, "It is my time—today is my time to start doing things differently. You do not have to be a Harvard graduate to understand this: You can change your entire world, right now, by changing your attitude.

You can not buy an attitude; I can not give you an attitude. Attitudes can be good or bad.

How about the term burnout? Ever heard of burnout? People come up to me all the time and say, "Reese, I am burnt out."

Let me give you my definition of burnout. It is a self-inflicted attitudinal injury. You want burnout? Go for it; nobody can stop you. On the other hand, nobody can make you. The best defense against burnout is personal growth, doing what you are doing right now: sitting and listening to somebody else. If you were educated yesterday and stop learning today, you are uneducated tomorrow. Take the time to learn. As long as you can grow personally and perhaps professionally, you will not burn out. Somebody might stop your professional growth, but nobody can stop your personal growth, short of your death.

Why is it that one man, one woman, will fall prey to a stress-related disorder, and the other will not? Is it a question of physical stamina? It might be. Exercise is important.

What about this complaint? "I spend too much time thinking about other people." If you have never heard this term, note it: responsibility absorption behavior. Everything that happens is your fault. That is not so. Even if they blame it on you; it is not so. But we start to get this responsibility absorption behavior where everything is our fault and we spend all our time thinking about other people. You believe that is true? Do you spend a lot of time thinking about the people you love? You say, "Gee, would not I love to spend more time with them." Then, when you are home it is always, "Do not talk to me now, I have had a bad day." Then you grab a beer and hit the easy chair and say, "Keep the kids away for an hour." You might start hearing, "I still love you, but I do not like you any more."

We have a tendency to think of ourselves. Think of the last time you made a sandwich in your kitchen. When you opened that loaf of bread, where did you reach? That is right; in the middle. You saved all that hard stuff for the people you love. Do not tell me you do not think about yourself. It is a natural tendency for self-preservation. And yet whenever you fall to your knees—and, by the way, that is probably one of the only places where you can not lose your footing; you ought to get on them more often—you blame other people because you are trying to worry about them.

Why not take some time out to take care of yourself? Why not realize that you are in an at-risk population statistically and do something about it. You do not have to be a statistic once you know you are in trouble. It is like dressing for combat. If you walk into combat not dressed for it, you are going to get hurt. If you walk in ready, you have got a chance. All I am telling you is to try to gird yourself with whatever enables you to survive this thing we are calling stress.

Perception is the key. How you perceive an event is how you are going to react to it. About eight or nine years ago I flew to Chicago to talk to the Tylenol task force on that cyanide case. It was the same story: the best in the world conducting a thorough investigation and getting nowhere. They were very unhappy. Where does that leave you? Normally, someplace else; maybe a bar. If you can not go to work and you can not go home, there are not many options. You are not going to sit around in the public library. You are going to go somewhere where you can mask your symptoms.

What I told them is basically what I would like to share with you now. It is not the identifiable stressful components of your job that normally create the stress problem. It is your reaction to them. As Carl Rogers and

other psychologists might say, "It is not what happens in life that matters, it is what you tell yourself about what has happened." What does this mean to me? Should I lose control? Is it worth getting sick over?

I will take you a step further, as I did there. You are not responsible for everything that happens in your environment. But you must accept responsibility for your reactions. You are solely responsible for how you react to events, even events you cannot control.

Keeping problems bottled up is a tremendous source of stress. You can do some pretty foolish things when you are under stress, and one of them is withdrawing—socially, professionally, and emotionally. The Freudian term for it is isolation of emotion. It is what has been labeled image armor. You do not have any idea what is going on in Jim Reese's life today, but here I am with an FBI image; there you are with an image. We look good. And no one will ever know if we hurt; nobody will know if we are sad; nobody will know anything about us. All you are going to know is what I tell you.

At some point you are going to have to get rid of that armor and share your problems with someone. You are going to sit down with someone who cares and say, "I have got some things I want to talk about; I have been carrying a lot of anger around with me." Yes, that is part of stress management, being able to speak your feelings and getting rid of this John Wayne or Calamity Jane complex that says we look tough and nothing can hurt us; that we are impermeable. It simply is not the truth.

The greatest difficulty in life is choice. You are a product of the choices you have made in life up to this point. Some were good choices; some were bad choices. Some things happened that you had no control over but you chose to cope or not to cope; you chose to progress in one direction or another.

It is one of the nicest things human beings can do, choose. Everything goes through our filter, and we make choices based on the information we filter. What I am trying to do is change your filter. Get your filter cleaned; start looking at life and asking what you are getting out of it. Let me improve my personal life so I can go out and do a great job for my company, knowing that when I get my time it is going to be for me and when I work for them it is going to be for them. That way Jim Reese does not come into the FBI office and put out personal brush fires all day. If I have my personal life in order, I can fly to Oslo and Boston because I know things at home are well. If they are not, then I have got to stop avoiding problems and get matters stabilized.

I would like to talk about a few stressors unique to executives. The first is power. Do you feel you have enough power? Are there times when you have a lot of power until the big decisions have to be made, and then your boss strips you of your power? When you do some-

thing wrong, does anyone forget? When you do something right, does anyone remember? Do you start to have a pity party, turn into a couch potato, just sit there and pout? That will get their respect if nothing else will, right? Power is essential, but you should not use it to shut people up. Power should enable you to get succinct explanations of behavior and then move on to the next task.

Another source of stress for you is the maintenance of interpersonal relationships. You have to be able to talk up, talk down, and talk laterally. You have to relate to everybody. The Chinese have a symbol for it. It says you have to do the greatest things, and you have to do the smallest things.

What can you do to manage stress? First, understand the difference between being happy and being successful. Did you know there was a difference? Did you ever think you could be happy without being successful? Have you ever seen anybody that by the world's standards was successful but was not happy?

Success is down the road. Success is somewhere out there for me, and if I ever achieve that level of success, do you know what I am going to do? I am going to look at still another level. So if I wait to be successful to get happy, what are my chances of being happy? They are starting to shrink, aren't they? If success is getting what you want, then happiness is wanting what you have.

Right this minute is when you should be happy, not waiting for something to happen in your life, not waiting for an ill parent to get well, not waiting for your child to pull his or her grades up. Of course, you may have to mourn and grieve, you may have relatives in the hospital, but they do not have to take your happiness away. In fact, you can bring them happiness!

I do not know when you plan to stop worrying and waiting, but I plan to stop right now. My time is up. The message in stress management is that you must be in control. You can do all the voodoo stuff; you can read all the books you want; you can say that stress is a non-specific response of the body to any demand placed on it. You can do all these things, but none of them work until you have a commitment. The difference between being committed and being involved is the difference between eggs and bacon: the chicken is involved; the pig is committed. You have got to be committed to a plan.

I hope you will get up in the morning and send yourself a good message. Read something good; believe in something besides just you. If you think you are just going to live 72 years and die and it does not matter, then we do not need to have this conversation. If you think your life has a purpose, get up in the morning and give yourself a good thought.

Get up and be thankful that you have got another day and you have family and friends. Tell yourself, I am

going to do things differently, I am going to change my attitude, I am going to start eating better, I am going to take care of this body. And, if I love something, I am going to take some time out to hug it. I am going to get

happy, and I am going to let success surprise me. Have some good goals in life, but do not give up today for tomorrow. Some people wait until the 11th hour, only to die at 10:30.

## MASS DISASTER AND CRIME SCENE RECONSTRUCTION SUMMARY

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This paper is a summary of what was a highly successful symposium on the Forensic Aspects of Mass Disasters and Crime Scene Reconstruction.

There has been one theme that surfaced several times during this symposium which is of a big concern to me. This is the question of how do we handle the stress that comes with the job. Jim Reese made a presentation on stress management (Reese 1992) at this symposium. Each person attending this symposium has faced, or will face, in connection with their work, extreme stresses. There are many ways to go about handling this. I am not a mental health professional. I see myself as sort of a practitioner. The focus of this paper is about how I feel about critical incidence stress; some of the things that our organization, the FBI Disaster Squad, as well as other organizations do, in trying to address this problem, and how it can make your plan better.

One of the things that has come up also in connection with this is the question of the value of humor. Many of those of us that attended this symposium, and the people we represent, sort of have a different approach to life. We have what some people refer to as black humor. This is really a coping mechanism. I think some of the humor that comes from fire departments, police departments, and others that deal with emergencies of this type, is some of the best in the world. You have to live through working a mass disaster or crime scene to experience it, to understand it, and appreciate it. It makes a difference because that ability to laugh is one of the greatest anecdotes to stress that I have ever been involved with, and I know it has paid off for me.

I remember my first disaster that I worked was the PSA crash in San Diego in 1978 (discussed by Cook at this symposium, Cook 1992). I did not know what to do as I really did not have much to do so I was assigned to assist others. I can remember the tension that was there the first day or two, and has been at every disaster I have been to since then. I remember along about the second day there was a fellow that held up a Timex watch that was still operating. He made a reference to the commercial that a Timex watch could take a licking and keep on ticking. It broke the tension and allowed us to look at things a little differently, to say, that is a person that can share a laugh.

I have seen and heard of other instances. In fact, I have some slides from the American Airlines crash in Chicago where someone had placed a bird in a body bag that had been found out at the crash site. That bird was opened up and one can see, through the slides they did fingerprinting on its' feet, passed it right down the line, even to the dentist. So these things happen naturally as well as someone just bringing it up.

One of my favorite stories, to illustrate this point, which may or not be true, involved a high ranking FBI official. The FBI Disaster Squad, years ago, responded to a crash in Rome, Italy. If you have a crash in a location such as Newark, New Jersey (those of you from Newark, I apologize), or any similar places, you do not find any of the FBI bigwigs wanting to go along. But with a location like Rome, they all want to go. We had a high ranking FBI official, who decided this would be a perfect opportunity to go along and enjoy Rome. However, even if you go on a trip like this we expect a little bit of a work ethic, to help out. So this individual was given the responsibility of sorting the flesh, and looking for friction ridge skin, and then taking a toothbrush and cleaning it up so our real workers could process it. One of the doctors there walks up and says, "geez, Les, what are you doing?" And Les says, "well, I am going through these body bags and when I find a piece of friction ridge skin I take this toothbrush and clean it up so my guys can work on it." The doctor looks and says, "well, Les, that is very interesting, but for your information, penises do not have friction ridges."

It is very important to have a sense of humor but a respectful sense of humor, probably is appropriate in most instances. At one scene I was on, a bus had run into a stream in Colorado. The crash killed a number of people, including children. There was a picture of a Colorado State trooper or police officer, alongside the scene, and he had a big grin on his face. Obviously, he was laughing and there was a lot of criticism of that. However, you had to be there, you have to laugh and find some way to cope with that stress. It would have been more appropriate to have gone behind the bus or sit in a squad car, to get away from the crowd, as there is such a thing as disrespectful humor. However, do not be afraid to have humor and do not be afraid to look at those

situations, and use those coping mechanisms. There is not one better than humor because everyone likes to laugh. I have talked to a number of people at this symposium. Humor exists in that special form among those of us and with those of whom we associate. It is a very powerful force. Do not be afraid of it, in fact, use it. It is one of the best stress-coping mechanisms you can have.

Another important topic that was discussed was how to deal with press relations, the media. You should be prepared to deal with the media as the media can be helpful. We learned the absolute necessity of planning. Few people like to take the time to talk about planning, however, we had some very good presenters. Grant Peterson did an outstanding presentation on the role of the Federal Emergency Management Agency (Peterson 1992). Our whole reason for attending this symposium starts with planning, and it can not end there. No one who left this symposium could say, "well I have my plan tied together." This is because your plan should be constantly changing.

The very difficult connection between local, state and federal emergency responders was also emphasized. It can be difficult to deal with all of the pressures and sensitivities involved in responding to a disaster scene. When the FBI Disaster Squad responds to a disaster scene, we fly out from Washington, and usually get to the scene 18-24 hours after the local people have been on the scene. The local responders have had 18-24 hours of having to deal with press and local politicians. On occasion, when the FBI Disaster Squad arrives, we can put people off a little. So it is important, when you arrive, after everyone else has been required to deal with all of the pressures of working a disaster scene, that you try to fit in and work together as a team. If you plan ahead and indicate what services you can provide, working with others will proceed more smoothly. Our plan must be ever-changing and adjusting.

One presenter reminded planners not to overlook the question of liability when devising your plan. Law suits can last for two, four or even six years and can take a great deal of your time. Therefore from the legal aspect, planning is very important.

We discussed all types of disasters, including tornadoes, hurricanes, volcanoes, earthquakes, air crashes, structural collapses, vehicle collisions, and the Space Shuttle Challenger disaster. Presentations were also made where scene reconstruction (actually crime scene reconstruction), would be important for criminal prosecution in train wrecks and mass murders, as examples. Also, presentations were made on profiling, skeletal identifications by anthropology, radiology, the uses of entomology, dentistry, fingerprints, and DNA.

A great deal of important information has been presented at this symposium and many will ask, not only

how am I going to respond to that, but how would my agency respond to it? This is a very important factor and this is the factor that kept coming up again: how are my people, as well as myself, how are we going to survive this? Are we going to become victims of this crash? In my opinion, most often people who work at disasters will become victims. In the worst case there could be an actual death based on the stress and post-traumatic stress that come from it, or at least some suffering. You do not have a plan if you have not decided how you are going to provide support to the people who have to deal with this stress.

The presentation by Supenski (Supenski 1992) from Baltimore County on the AMTRAK crash, provided information on support not only for the workers, but also the local residents. Support personnel went into the neighborhood and addressed the neighborhood's needs, as that neighborhood was greatly affected by that train crash. He had an excellent suggestion that you must look not only at the actual victims, but to the next set of victims, the rescue workers and the people out in the neighborhood, to help them cope. Many of our police cars say "To Protect and To Serve." Supenski gave an excellent example of the responsibility of the Baltimore County Police Department, in going out in a very proactive manner and helping people with their problem of property losses and their ability to cope after a disaster has occurred in their neighborhood.

Critical incident stress debriefing is a way to help workers cope. Immediately after the PSA crash in 1978 (Cook 1992), the fire fighters, rescue personnel and police officers, responded to a report of a plane crash with an idea they were going to save people. These rescue workers did not find anybody alive. The crash scene was so bad and wide, that they literally walked around in the remains of the victims. It was very hot and it did not take long before it started to smell. At that time, nobody knew about psychological stress among emergency workers; it was just a fact of life. They had some tremendous problems after that and ended up with years of counselling. They learned from that experience to develop critical incident stress debriefing.

There was a plane crash a number of years ago that involved a large number of people being killed, over 100. That airline had a large number of employees on board. That airline asked, or ordered, one of their pilots, to go to the morgue to identify the airline employees who were on board. There was no one to be recognized; it was terrible. But that pilot had to stand there and try to identify the airline employees by identifying the crew uniforms. He also stood there when the dentist or the pathologist would ask, if this is the body of a specific individual and he would respond, "yes, I dated her or I flew for a number of months with him." This person

started having some problems including sleeping problems. This continued on through the disaster operation for months after. This person later drove his pickup truck over a cliff, which some people said was an accident. He was the extra victim.

Be very careful in your disaster operations in trying to eliminate people who knew the victims. It is extremely difficult to work in that area where you have some personal relationship with the victims. You are basically inviting problems. It is difficult sometimes to know who is involved and who is not, but that is a consideration you ought to look into as you are lining up your people. Do not place someone in a difficult position, be it an airline representative, a police, fire, or any other emergency services person. You are going to, very likely, have some problems with that.

A few years ago there was a shooting at a McDonalds in San Isidro, which is in the San Diego area. There were 21 people killed, including a number of children. A police sniper killed the perpetrator. They had very few stress disorders from their people because they had instituted an educational program that taught them ahead of time. They had people on the scene and they went through debriefings and follow-up counselling afterwards. The experience of San Diego and others has shown that when there is a very active stress counselling program, there are very few disorders for post-traumatic stress disorder.

Another example of how stress can effect people happened following the earthquake in Loma Preata. It has been my experience that coroners and medical examiners handle their jobs very well. When I have asked them how they cope, many frequently respond that it is just part of their job. As you may recall there was a very slow recovery effort based on the fact they had to dig through all the debris. A number of the coroners' bureau people ended up going on the scene and became rescuers, rather than doing their normal coroner's duties. A couple of their people that had to be sent home from stress related concerns. Their roles had changed and as a result it was necessary to do psychological debriefings on some people that they would not normally have to.

Critical incident stress debriefing works, and it can work for you. Critical incident stress debriefing systems arose basically after the San Diego crash in 1978 and some of the concerns that came from it. The leader in that field is Dr. Jeff Mitchell from the University of Maryland, Baltimore County. It works on two basic tenants. One, is that when these debriefings take place, and they are structured debriefings, everything that goes on in that debriefing room is confidential. Anyone who violates that confidence, be it a member of the debriefing team, or any person being debriefed who can not keep that confidential, is not allowed to participate. Two,

it is simply a matter of the people who are involved in the incident talking about it, and the others listening. There are no great skills if you are thinking about forming one of these teams as to who should be on it. It should be someone who is basically a peer. You should have a mental health professional involved in the beginning. Your mental health professional should be someone who has an expertise in critical incident stress.

It has worked well, and we are also expanding now into peer support activities. These debriefings will usually last anywhere from 2-4 hours. Again, it consists of the people who have been through the incident, and that peer support that is forming the debriefing team. But who should go through this? I think automatically you recognize a police officer, fireman, rescue worker, and particularly if you have a lot of duty death. For example, if you had a fireman killed, you are going to have to go through one of these things. There are many people outside of the immediate scene that need to be included, for example, ambulance drivers who haul away the victims and the radio dispatchers.

In summary, many aspects of mass disaster and crime scene reconstruction were presented at this symposium. One important element was support to those whose job deals with mass disasters and crime scene reconstruction. Critical incidence stress debriefing plays an important role in this area.

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**SECTION II**  
**EXTENDED ABSTRACTS**

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## IDENTIFICATION OF MT. ST. HELENS VOLCANO VICTIMS

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The volcano at Mt. St. Helens, in Washington State erupted May 18 and again on May 25, 1980. This eruption left 34 known dead and 27 missing. Stages of this operation were: volcano, destruction, environment, victim recovery, victim identification, autopsy, statistics and conclusion.

The airport at Toledo was the base for recovering and examining victims. A U. S. Army detachment set up a self-contained field morgue. It was located across from the airport buildings so that, because of the contour of the land, we were not visible at eye level. The morgue was a tent and the bodies were stored in two refrigerated trailers. We had our own water supply, privies and diesel electric generator. National Guard reservists acted as couriers. The FBI Identification team obtained records, fingerprinted and took care of personal belongings. A helicopter flew back and forth to the mountain and was the only mode of transportation in finding and transporting human remains.

Unlike most disaster, the volcano presented a vast variety of conditions under which victims died. There were ash, gases, anoxia, water, steam, extreme heat, extreme cold, concussion, falling rock, falling trees, lava flow, not to mention horror and fear. I believe this was the first time volcano victims have been examined first hand so soon after dying. Most victims died of ash asphyxiation. Eyes and noses were rubbed raw. The mouths were open and filled with ash. Three of the children showed maggot infestation. The other bodies were as if sterilized and nearly odorless. In three days in an open tent I counted only two flies.

A remarkable phenomenon was observed relative to the conductivity of heat. Skin exposed to the elements was rather normal appearing. Skin covered by cloth but not in contact appeared pink as if sunburned. Skin in contact with cloth showed third degree burns. Japanese doctors who observed the atomic bomb destruction saw similarity and attributed this to rapid steam buildup under clothing.

One couple was in a tent when killed by a falling tree. Their coloration was very yellow compared to he

others. At autopsy their tracheas were clear because they died of trauma indoors. Conversely, in the typical ash victim the trachea were packed tightly with ash. When the trachea were cut open the ash appeared in several boluses depictive of gasps. Charting the dentition was very difficult because the ash was so plentiful, fine and tenacious.

A newspaper man was photographing the dome buildup in the crater and announced the eruption to the world. He ran to his automobile and proceeded to take a series of pictures right up to the time that he died. The car filled with hot ash and he was decapitated but visually identified. A temperature gauge registered 330°C when it failed. We found cameras held together by plastic and rubber. The metal parts had mostly melted. In most cases the film was still good. Incinerated victims were not typical of the gas, diesel, or kerosene fires we were more accustomed to.

I am an oral and maxillofacial surgeon and was awed at the total of dissection especially of the mandibular condyles. Fingerprinting gave the FBI a variety of problems. From quite normal to shrivelled, shrunken, to an almost asbestos-like texture. Acrylic dental prostheses were unaffected due to their low heat conductivity.

Twenty-one people died of ash asphyxiation, three of thermal burns, two from burns in the hospital and five of unknown causes. Thirty-three were identified, 19 were known missing and 20 were presumed missing making a total of 80 victims. Following the identification process, the bodies were air lifted to the state medical examiner offices in Portland, Oregon, and Seattle, Washington, for autopsy and more detailed examination.

The New England Journal of Medicine (10/15/80) indicated surprise that so many victims were asphyxiated by volcanic ash instead of poisonous gases as earlier suspected. They also stated that dust masks or respirators might have saved some lives. However, no protective device would have helped people who were too close to the blast and heat of the eruption. In conclusion, volcanos give many warnings before they erupt. People should take heed and evacuate the danger areas.

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## IDENTIFICATION OF ETHIOPIAN NATIONALS BY EXCLUSION

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A Twin Otter Aircraft with 9 Americans, including Congressman Mickey Leland, and 7 Ethiopians on board departed Addis Ababa on August 7, 1989. The aircraft did not arrive at its destination, a refugee camp in Western Ethiopia. Searchers found wreckage on a remote mountain-side near Gambella about one week after the crash. All aircraft occupants died instantly in the crash. The extensively fragmented, severely burned and partially decomposed bodies were flown to Addis Ababa for identification.

The Office of the Armed Forces Medical Examiner, Armed Forces Institute of Pathology (AFIP) was requested to identify the remains recovered at the crash site. The identification team consisted of AFIP forensic pathologists, AFIP forensic odontologists, FBI fingerprint specialists, a civilian forensic anthropologist and support personnel. Identification activities began 10 days after the crash in tents erected at the Addis Ababa airport.

The condition of the remains complicated identification, but the passenger manifest was well-documented. Traditional methods of positive identification, dental and fingerprint comparisons, identified eight of the Americans. Standard anthropological methods identified the remains of the ninth American.

Available pre-mortem records were insufficient for positive dental or fingerprint identification of the Ethio-

pians. The intimate association and intermixture of unique personal effects with remains allowed presumptive identification of two Ethiopians. The remaining five Ethiopians were identified using an exclusion matrix.

A team composed of Ethiopian and American identification specialists, carefully reviewed each set of remains to verify and document available medical, dental and anthropological data. A separate team of American and Ethiopian physicians independently collected, verified and reviewed all available pre-mortem information.

The combined teams then compared the pre-mortem and postmortem data for all possible combinations of unidentified remains and passengers to identify impossible combinations (specific exclusions). The following data types produced specific exclusions: dental, radiological, sex, race, age and height. The combined exclusions, recorded exclusions on a 5 x 5 matrix, clearly demonstrated unique associations (identifications) between sets of remains and those previously unidentified Ethiopians known to be on the aircraft.

This approach to identification by exclusion maintained objectivity during data collection and assured uniqueness of remains-name associations. The matrix also demonstrates the strength and redundancy of each exclusion.

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# **THE CRASH OF UNITED FLIGHT 232: THE USE OF FORENSIC PERSONNEL IN THE COLLECTION AND IDENTIFICATION OF THE VICTIMS, THE PSYCHOLOGICAL AFTERMATH AND RECOMMENDATIONS**

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On July 19, 1989, at 4:10 p.m., United Flight 232 crashed on a runway at the Sioux Gateway Airport, Sioux City, Iowa. Rescue operations took approximately two hours with 185 surviving and 111 dead. The Iowa Department of Public Safety (DPS) dispatched 12 members of the Iowa Department of Criminal Investigation Criminalistics Laboratory and ten special agents to assist in the recovery and identification of the victims.

On July 20, a coordinate baseline method of measuring was used on the main and crossing runways to establish victim location. Spray paint was used to mark the runways at 30 foot intervals. Three collection teams were formed. Each team had a pathologist, a scribe, a photographer, a measurer, two body handlers and a tagger. Tags, paint or stakes were used to mark bodies, body bags and body location. Photographs were taken of the victims, with their assigned numbers, where they were found. After the victims were removed from the crash site, they were placed in refrigerator trucks which were located outside the morgue. In a period of four hours, 54 bodies were removed from the field. Another team was then set up to recover bodies from the fuselage of the plane. The bulk of the fuselage came to rest inverted in a corn field. Because of this, body removal was delayed until the structure could be stabilized. Two cranes were connected to the remaining landing gear to lift the plane while railroad ties were stacked to support the wings. The 47 bodies located in the fuselage were tagged, photographed in position and then removed. Some of the victims were still strapped into their seats. Because of tight quarters and a partially collapsed cabin, it was necessary to cut out and remove those seats from the plane before the victims could be removed from the seats. This process took five hours.

A temporary morgue was set up in an Iowa Air National Guard hanger. Room dividers were used to form six separate areas; a reviewing area where each body was photographed along with clothing, jewelry, and any physical characteristics to aid in identification; an X-ray area for full body X-rays; the FBI fingerprint area that examined 111 victims with 33 identified; a dental area where 17 dentists examined 111 victims, with 101 identified; an autopsy area that had 16 people working at four tables; and an embalming area that had about 30 people working at six tables. The autopsies

determined the cause of death for 35 victims to be from smoke inhalation and 76 from head, neck and chest injuries. The autopsies were completed in four days with all victims identified five days after the crash.

Most emergency workers experienced critical incident stress either at the scene or shortly after returning home. Debriefings were offered at the scene and also after returning home for all interested employees. All DPS employees that worked at the crash scene and morgue are still working for the DPS with no apparent signs of post traumatic stress disorder.

Systematic crime scene investigative procedures are essential in the identification of victims of a mass disaster. Because of previous experience with homicide investigations and autopsy procedures, forensic crime scene personnel are well prepared to handle the victim processing and critical incident stress.

Recommendation for future improvement in three major areas include:

**Management** - The establishment of a chain of command focusing on specifying a person in charge, developing a comprehensive system of worker identification, stricter security and streamlining morgue paperwork.

**Work conditions** - Improvement should focus on appropriate morgue ventilation (for example, the embalming teams were working close to the autopsy teams causing embalming chemicals to irritate some team members), the monitoring of team members to insure adequate breaks are taken and workdays no longer than 12 hours.

**Personal needs** - Should secure comfortable accommodations (many motel rooms were secured by the news media), proper clothing and supplies, mental health care which should include mandatory group debriefings and recognition and commendation of all persons assisting in the disaster is essential. This should be included in the disaster plan.

Gratitude is expressed to the Iowa Air National Guard, volunteers of the American Red Cross, the Salvation Army and many others for their support throughout the disaster.

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**THE METHODS OF  
SEARCHING, PRESERVING, AND DOCUMENTATION  
OF THE GALAXY AIR CRASH SITE IN RENO, NEVADA  
ON JANUARY 21, 1985**

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Reno, Nevada

On January, 21, 1985, shortly after midnight, Galaxy Airlines Flight 203 crashed after take off from Reno Cannon Airport. The plane came down in a motor home sales lot and spread debris across U. S. 395 thus causing the death of all but one person on the flight.

The method of searching the crash site at night was both by air and ground. We used a helicopter with high intensity spotlights to search the area around the crash site for any possible survivors. Due to the fire that was caused by the crash, ground crews were used to search the areas adjacent to the fire. We were very fortunate that the crash took place late at night and that it came down in an uncongested area thus eliminating any additional deaths on the ground.

In order to preserve the crash site, U. S. 395 was closed and the traffic was routed to alternate routes in the city by the Reno Police Department. In addition, the area around the crash site was closed and reserve deputies from the sheriff's office were used to secure the scene. After the portion of the scene that covered the freeway was documented and the evidence was collected, a barrier was built around the crash site. Thus, the scene could not be seen by the drivers when the freeway was opened. This reduced the traffic slow downs by drivers and reduced the potential for traffic accidents in the area of the crash site.

In order to document the scene, a grid was laid out in 20 foot X 20 foot squares. Items of evidence and the victim's bodies were triangulated within these squares. Prior to collecting these items, they were documented through photography. Once the outer portions of the

crash site were documented, the squares were broken down into four smaller squares in one large square. Once we were into the major portion of the crash site, a snorkel unit from the Reno Fire Department was brought in. This unit was used as a platform to complete the still photography. The video photography of this crash site was completed from ground level allowing for the recording of the victim's body locations and their related location numbers.

Once a body was removed from the site, it was placed in a body bag and a tag was attached to the bag indicating the location it was found. This made it possible to position the bodies relative to a seating chart that was supplied by the airline. This made the identification process of the dead easier. Once a body was bagged and tagged, it was placed in a refrigerated truck and then the bodies were transported to the temporary morgue at the County Fair Grounds.

In order to document the location of the crash site, we had the Nevada Air National Guard Aerial Photography Unit conduct an aerial reconnaissance of the scene. This permitted us to see the scene in one photograph and to be able to reposition the crash site at anytime when asked to by the courts or the Federal Aviation Administration (FAA).

By using these methods of preservation, documentation, and the cooperation of all agencies involved, it allowed for this terrible situation to be handled in an effective and expedient manner. These methods also allowed the FAA the information they needed to reconstruct the scene and determine the cause.

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## **BODY AND EVIDENCE RECOVERY DURING NEW MEXICO 1980 PRISON RIOT**

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New Mexico experienced a riot in its maximum security prison in Santa Fe, in February 1980. The riot started in the late hours of Friday and ended on Sunday afternoon. The capture, torture, and beating of twelve correction officers, the injury of at least 90 inmates and the death of 33 other inmates all occurred prior to the state regaining control. The regain of control occurred after negotiations between the Governor, corrections department and inmates. No deaths occurred during the recapture action.

Local and state law enforcement officers maintained perimeter control and prevented the escape of any inmates during or following the riot. The New Mexico National Guard assisted in perimeter control, supplied nourishment, provided shelter to those on both sides of the fence, and performed the actual sweep to put control of the facility back in the hands of the corrections department. In addition, they administered triage and transportation to those inmates who were either injured or deceased. The New Mexico National Guard was a well disciplined group and performed invaluable service during and after the riot conditions.

The New Mexico State Police Crime Laboratory had a two man team assigned to the riot. This presented problems from many aspects. The actual coordination of actions of all groups was attempted by New Mexico State Police officials who failed to properly program the actions of the crime laboratory team and those of the New Mexico Office of the Medical Investigator (OMI). As a result, the OMI teams were sent in for body recovery before the crime laboratory had observed, photographed, or collected any evidence from the majority of the crime scenes. The crime laboratory and the New Mexico State Police also failed to properly collect, tag, and identify weapons of various sorts as they were surrendered by inmates or collected from within the prison. Weapons were collected and then dumped together into large trash cans. Processing of these weapons at the crime laboratory was also to some degrees superficial as a typewriter roller (alleged homicide weapon) was found to contain hair by the attorneys during the trials that followed.

The local OMI organized and assigned one member to stand by the local hospital and coordinate activities there while three others and a pathologist proceeded to the prison. It was determined that at least three groups would cover the modified H design of the prison. The pathologist was designated to receive bodies, perform identifying photographs, seal body bags and arrange transportation. The transportation was conducted by the New Mexico National Guard. The entry teams, all civilian, were teamed with local city police detectives/volunteers who had either completed previous OMI training or had years of homicide investigation. Each of these officers were armed and actually captured inmates still loose within the facilities. Also accompanying each team was one volunteer corrections officer to be utilized as a guide and for tentative identification of the deceased, if recognizable. Additionally alternating teams of the New Mexico National Guard volunteers were utilized for body transportation to the check point on the outside. Adverse conditions (flooding, fire, tear gas filled hallways, and approaching darkness) and the emphasis for evacuation as quickly as possible resulted in the OMI team not photographing the crime scenes as adequately as possible.

All autopsies were conducted at the New Mexico Office of the Medical Investigator Albuquerque facility. Refrigerated trailers were brought in to handle the influx. Also provided was maximum technical support and a psychologist to deal with post traumatic effects of such massive carnage. This service was not made available to those members who were actually involved in the recovery efforts.

Prosecution efforts that followed were to last over two years and cost nearly \$2,500,000. There were 39 inmates involved with nine trials resulting in 25 convictions for murder and 79 for lesser crimes committed during or shortly after the riot.

An organized team approach is the key to processing of any crime scene, whether it involves one or 33 deaths. A reference outline for disaster handling appears in Table 1.

**Table 1. DISASTER HANDLING - A REFERENCE OUTLINE**

<p><b>I. Background</b></p> <p>A. Determine the types of disaster</p> <ol style="list-style-type: none"> <li>1. Minor - five or fewer dead</li> <li>2. Major - six or more dead</li> </ol> <p>B. Ascertain the location and climatic conditions</p> <p>C. Acquire any statistics and history on the general situation, that is, floor plan, numbers of individuals present, etc.</p> <p><b>II. Pre-scene Activities - Make arrangements for</b></p> <p>A. Security</p> <ol style="list-style-type: none"> <li>1. Scene - General Area <ol style="list-style-type: none"> <li>a) Perimeter - allow entry to persons with official business only</li> <li>b) Personnel - armed personnel with restraint capabilities should accompany laboratory staff in order to relieve staff of all responsibilities other than processing the scene</li> <li>c) Lock-up a safe area for individuals needing containment</li> </ol> </li> <li>2. Scene - Specific Area <ol style="list-style-type: none"> <li>a) Determine estimated time unprotected, that is, time from occurrence to occupancy</li> <li>b) Maintain security (see II, A, 1) until laboratory has completed processing and releases scene</li> </ol> </li> </ol> <p>B. Triage Center - for the purpose of</p> <ol style="list-style-type: none"> <li>1. Identify condition of individuals involved <ol style="list-style-type: none"> <li>a) Well</li> <li>b) Injured</li> <li>c) Dead</li> </ol> </li> <li>2. Relocation arrangements - location and transportation to <ol style="list-style-type: none"> <li>a) Containment area - within walking distance</li> <li>b) Medical facilities - ambulance, truck, helicopter</li> <li>c) Morgue facilities - ambulance, truck, helicopter</li> </ol> </li> </ol> <p>C. Auxiliary Locations</p> <ol style="list-style-type: none"> <li>1. Telephone and/or radio should be present at scene, triage center, medical facility and morgue facility</li> <li>2. Bodies and body parts to morgue with x-ray, autopsy, and cooler/refrigeration capabilities: NOTE: General Formula for a Major Disaster - Four (4) refrigeration trucks for each 80+ bodies 1 truck for adult males 1 truck for adult females 1 truck for miscellaneous parts 1 truck for cases completed/released</li> </ol> <p>E. Auxiliary Personnel - on stand-by basis</p> <ol style="list-style-type: none"> <li>1. Next to kin <ol style="list-style-type: none"> <li>a) Identification (physical, medical, jewelry, etc.)</li> <li>b) Funeral home arrangements</li> <li>c) Grief counseling (see II, E, 3, c)</li> </ol> </li> <li>2. Local Police I.D. Department or FBI - for fingerprint assistance</li> </ol> <p>3. Medical Examiner</p> <ol style="list-style-type: none"> <li>a) Identification by police records, dental charts, x-ray and fingerprint records</li> <li>b) Establish procedure for notifying next of kin</li> <li>c) Responsible for grief counseling (see II, E, 1, c)</li> </ol> <p>4. Law Enforcement - National Guard</p> <ol style="list-style-type: none"> <li>a) Security</li> <li>b) Assist laboratory staff with processing scene (under direction)</li> <li>c) Transportation and food</li> </ol> <p>5. Non-law Enforcement Specialists (Firemen, Physical Anthropologist, Forensic Odontologist, etc.)</p> <ol style="list-style-type: none"> <li>a) Advise on safety of burned areas</li> <li>b) Search for and physically reconstruct bones</li> <li>c) Match individuals and objects to bite marks and bruises (photo enhancing)</li> </ol>	<p><b>F. Auxiliary Equipment</b></p> <ol style="list-style-type: none"> <li>1. Camera, flash, film, fresh batteries</li> <li>2. Body evidence bags vs. body crash bags (\$10.00 vs. \$50.00+)</li> <li>3. Seals, tape, tape measure, marker, clip board, 3 X 5 cards, paper</li> <li>4. Block of consecutive case numbers</li> <li>5. Portable flood lights</li> <li>6. Gas masks, surgical gloves, surgical masks and odor blocker (contact the author for observations on various odor blockers)</li> <li>7. Knee boots, snow boots</li> <li>8. Weapon or personal armed guard</li> </ol> <p><b>III. Scene</b></p> <p>A. Teams - order and activity</p> <ol style="list-style-type: none"> <li>1. Swat - to clear and secure area (prior to)</li> <li>2. Crime Laboratory - to process; including photos, diagrams, and evidence collection (see III, B, 2, c) (prior to)</li> <li>3. Medical Examiner <ol style="list-style-type: none"> <li>a) Inside scene - two staff to each body; photo body and area, tag for location, I.D., injuries, bag, transport to triage center (by National Guard)</li> <li>b) Triage center - one staff; initial I.D. photo (polaroid), assignment of numbers, log maintenance, seal bags, supervise storing of bodies pending transportation to morgue</li> </ol> </li> </ol> <p>B. Anticipated</p> <ol style="list-style-type: none"> <li>1. Problems <ol style="list-style-type: none"> <li>a) Unauthorized persons present (inmates, police, legislators, clergy, clean-up, and contractors)</li> <li>b) Fire, smoke, tear gas, water, darkness</li> <li>c) Time pressure from other agencies</li> <li>d) Lack of organization in command/co-ordination of scene activities</li> </ol> </li> <li>2. Recommendations <ol style="list-style-type: none"> <li>a) Secure area (both inside and outside)</li> <li>b) Designate one person to be in charge of scene and release in the following order: <ol style="list-style-type: none"> <li>(1) Secure area</li> <li>(2) Admit crime laboratory</li> <li>(3) Admit medical examiner</li> <li>(4) Admit all other (see III, B, 1, a)</li> </ol> </li> <li>c) Crime laboratory process as a normal crime scene (two laboratory staff per each death)</li> <li>d) STAY COOL, DON'T RUSH, DON'T PANIC</li> </ol> </li> </ol> <p><b>IV. Post Scene</b></p> <p>A. Morgue</p> <ol style="list-style-type: none"> <li>1. One person responsible for log, count, and location (use large wall chart)</li> <li>2. Preliminary description (easiest first)</li> <li>3. Detailed description (easiest first)</li> </ol> <p>B. Medical Aspects</p> <ol style="list-style-type: none"> <li>1. I.D. board/chart - include notes on <ol style="list-style-type: none"> <li>a) Location (for-recheck)</li> <li>b) Physical description</li> <li>c) Dental</li> <li>d) Tattoos</li> <li>e) Old fractures</li> <li>f) Fingerprints</li> </ol> </li> <li>2. Pre-death factors - complete homicide work-up autopsy including toxicology and carbon monoxide level</li> <li>3. Reconstruction of injuries - utilize milar tracings, photos, and photo enhancing</li> <li>4. Documentation for teaching materials</li> <li>5. Anticipation of litigations and allegations</li> </ol> <p>C. Court Trials - anticipate minimum of 3-5 years prior to trial</p>
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## FACIAL PHOTOGRAPHIC SUPERIMPOSITION

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Identifications based on the comparison of dental characteristics, medical radiologic characteristics or fingerprint features are the norm in the U. S. These methods are scientific in nature and all insure a positive identification.

Personal effects such as clothing, jewelry and wallets have been used to establish human identifications. The use of personal effects is not a scientific method of establishing an identification.

At times, the medical examiner or coroner is faced with the task of establishing an identification for an individual for whom no medical, dental or fingerprint records can be established. If a photograph of the putative victim can be obtained, it may be possible to establish an identification through a technique known as photographic superimposition.

When using photographic superimposition, it is important to remember that a full face, smiling, pre-mortem photograph must be available. If the teeth are not visible, do not proceed with the technique as there will be no scientific basis for any conclusions.

The skull is orientated in an attempt to obtain the best possible match of the position of the face in the photograph. One specific location on each of three axes is the position of best match of the skull to the position of the face portrayed in the pre-mortem photograph.

Starting at the first position on each of the axes a photograph is taken. These exposures are then contact printed. The best match is selected from the contact

prints. The corresponding negative is then enlarged to life size. Attention is now turned to the pre-mortem photograph which is enlarged to life size.

The life size photograph of the skull is secured on a flat surface. The transparency with the life size print of the pre-mortem photograph is now placed on top of the postmortem film. The transparency is now precisely positioned to allow maximum overlap of similar anatomical features.

The concordance of the following features is noted: outline of the skull compared to soft tissue outline of the face, nasal aperture to nose, orbit to eye, brow ridges to eye brows and forehead, zygomatic process to cheek bone support, and most important, exact superimposition of the teeth in both size and angular position.

Gross discrepancies between the two films will serve to rule out the individual as the deceased. If the discrepancies are minor, there may have been an error in selection of the proper photograph of the skull. Another skull photograph may be selected, enlarged and printed, and then superimposed.

When all anatomical details match, but no other detail rich feature is found, the choice of a "consistent with" opinion is most appropriate. The presence of a detail rich feature such as brow furrow, skeletal trauma or obvious skeletal disfigurement may allow the forensic investigator to give the opinion of positive identification by the superimposition of skeletal and photographic images.

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# HEAT INDUCED CHANGES IN HUMAN SKELETAL TISSUES

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Bush fires in Victoria (Australia) cause massive destruction of property and considerable loss of animal and human life. These bush fires cause substantial monetary loss (Luke and McArthur 1986). Eucalyptus forest, the natural flora predisposes to such disasters and in the aftermath there is very little evidence left. Household materials are either completely destroyed (for example, wood and plastics) or paradoxically virtually unchanged or show no change at all (for example, large steel objects). By contrast, the human skeleton is remarkably resistant to destruction by fire yet exhibits permanent, subtle physical and chemical changes that are dependent upon the temperature of the fire to which it has been exposed. The aim of this study was to investigate the course of change of ultrastructure and phase transitions in human bone and tooth tissue when heated through the temperature range 200°C to in excess of 1600°C.

## METHODOLOGY

Samples of female bone in the form of 1 cm thick transverse sections of the femur were supplied from the Department of Forensic Medicine, Medical University of Szeged, Hungary. Additional bone samples were from both sexes were collected from the Victorian institute of Forensic Pathology (VIFP). The teeth were collected from either the Royal Dental Hospital of Melbourne or the VIFP.

The sections of human femoral bone and whole teeth or sections from whole teeth were subjected to heat treatment for two hours in an atmosphere of air unless otherwise stipulated. Some samples were heated for 40 hours as a check that the observations made after two hours represented conversion at that temperature. After each heat treatment, specimens were examined by light microscopy and scanning electron microscopy (SEM) and subjected to powder X-ray diffraction (XRD) analysis.

## RESULTS AND DISCUSSION

Macroscopic and low power microscopic examination of samples revealed characteristic color changes dependent upon heating rather than other factors such as the age of the subject. Over the range 200 to 600°C bone color changed from ivory through tan, to dark charcoal and grey before assuming a porcelain white color which then persisted from 800 to 1400°C. Samples at 1600°C which melted, or vaporized and recondensed adapted a light blue hue. Dentine showed similar color changes to bone. Scanning electron microscopy showed ultrastructural changes that were temperature dependent at temperatures over 200°C. Drying cracks appeared in the range 200 to 600°C but the underlying structure remained intact. At 600 to 800°C considerable differential shrinkage occurred which tended to enhance the microstructural features of the bones architecture. This corresponded to appreciable reduction (approximately 20%) in external sample dimensions.

At high magnifications it was observed that the original bone crystals which had been beyond the resolution of the SEM had recrystallized or sintered into larger individual hexagonal crystals. Despite these appreciable crystal changes the original bone structure could be detected. On heating at higher temperatures crystal growth continued accompanied by progressive loss of the original bone structure.

The XRD patterns of bone heated to temperatures of 200, 400 and 600°C showed broad spectra indicative of a poorly crystalline hydroxyapatite material. Bone samples heated to 800, 1000 and 1200°C gave sharp spectral lines which were identified as a form of hydroxyapatite. This indicates a sudden increase in crystalline size between samples heated to 600°C and those heated to 800°C. Heat treated enamel showed well defined peaks of hydroxyapatite in the temperature range 200 to 1200°C. Dentine displayed similar crystalline size changes to bone.

Trace quantities of whitlockite ( $\beta$ -tricalcium phosphate,  $\beta$ -TCB) are first detected in XRD patterns of bone heated to 1200°C, enamel heated to 600°C and dentine heated to 800°C. There were greater quantities of  $\beta$ -TCP in bone heated to 1300°C.  $\alpha$ -tricalcium phosphate ( $\alpha$ -TCP), tetracalcium phosphate (calcium oxide phosphate, COP) and hydroxyapatite are the main phases present in all samples heated above 1300°C. It appears that as the temperature is increased,  $\alpha$ -TCP increases at the expense of  $\beta$ -TCP.

The 13, 44 and 77 year old samples heated to 1600°C showed an increase in the ratio of hydroxyapatite to  $\alpha$ -TCP and COP with increasing age at this temperature. No other major differences were observed at this temperature. No other major differences were observed in the XRD profile due to the age of the victims's bone in the range 13 to 77 years.

Preliminary work to compare samples recovered from scenes with our calibration data is underway. Further work is proposed to investigate the influence of different atmospheric environments including the contribution of accelerants.

A full understanding of the microstructural and microcompositional changes that occur in the human skeleton subsequent to ignition will enable the genesis, propagation and spread of bush fires to be reacted with more precision than at present. These findings are of relevance to those reconstructing automobile and aircraft crashes.

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## COMMUNICABLE DISEASE CONSIDERATIONS IN MASS DISASTER MANAGEMENT—AN OVERVIEW

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Communicable disease hazards can present a serious and frequently overlooked threat to the health and welfare of survivors and relief workers following natural and man-initiated catastrophes. Historically, epidemics of typhus, plague, dysentery, small pox and other contagious diseases have been a regular concomitant of war, famine and disasters of all types. In recent years, however, communicable disease surveys conducted during and after natural disasters suggests that major outbreaks of communicable diseases are uncommon and easily controlled. In part, this may reflect the availability and effectiveness of modern public health interventions implemented during relief operations. It should be noted that the instances where the communicable disease aspects of disaster management are overlooked or unavailable the casualties and the economic losses resulting from post-disaster epidemics may far exceed those directly attributable to the event itself.

The transmission of communicable disease following disasters may be influenced by six main factors: 1) the diseases present in and around affected populations prior to the event; 2) environmental and ecologic changes resulting from the disaster (for example, the creation of new vector-breeding sites; 3) population movements; 4) damage to public utilities and sanitation facilities; 5) the disruption of communicable disease control and public health programs; and 6) altered individual resistance to disease. The toll enacted by each of these factors is largely dependent on predisaster recognition and planning. The hampered recovery of large numbers of widely dispersed remains may be hampered drastically increasing filth fly and carrion insect populations. Likewise, disruption of sanitary community services, displacement and confinement of the survivors, and improper disposal of domestic animal carcasses, may all contribute to the generation of pathogens, mechanical insect vectors, and

pest populations resulting in a vastly increased risk of communicable disease outbreaks.

Encountered natural postmortem changes leading through decomposition toward skeletonization frequently invoke fears among relief and recovery teams of some sort of plague. With rare exceptions, however, mere contact with decomposing bodies does not, in and of itself, create any specific community health risk. There are of course other reasons for the rapid disposal of corpses and carcasses, such as the direct offense and the hazard from insects and rodents, particularly in the tropical climates. The precipitate disposal of human remains by mass cremation or burial and the use of lime as a disinfectant may be hygienically unnecessary except in extraordinary circumstances and may hinder disaster investigation and victim identification.

Of major concern is the threat from the Human Immunodeficiency Virus (HIV). The HIV is reported to be very labile obligate intracellular infectious agent. To date, there have been no reported infections or seroconversions derived solely from postmortem contact. Clearly even simple yet prudent precautionary measures such as double gloving, wearing masks, protecting skin breaks, avoiding re-capping needles, and proper disposal of other sharp objects is warranted. Still, the more worrisome contact is with the hepatitis B virus despite the availability of an HIV-free vaccine.

While natural and man-initiated catastrophes rarely produce new diseases, they often increase the incidence and transmission of pathogens endemic to the region affected, particularly in developing countries. Mass disaster contingency plans and management strategies must adequately address the prevention and control of communicable disease hazards as well as the more conventionally defined aspects of casualty planning.

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# **DEVELOPMENT OF AN EMERGENCY PLAN DURING THE LUMA PRIETA EARTHQUAKE**

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On October 17, 1989 at 5:04 p.m. the Luma Prieta earthquake rocked the northern area of California causing severe damage to certain parts of the city of San Francisco and the surrounding area. This earthquake registered 7.1 on the Richter scale

United States Park Police officers patrolling in the area of Marina Green park, observed the ground rising and falling, splitting open in numerous places. After it stopped, realization quickly set in. Smoke and fire was seen above the rooftops in the Marina District. People were fleeing their homes for the open areas in hope of finding a safe haven from falling debris. The pungent odor of natural gas permeated the air creating an atmosphere of near panic.

## **COMMUNICATIONS**

The duty supervisor verified that the communications system was still operational. The emergency generator had come on, the repeater links had switched to battery power, and the system was fully operational within seconds. The system provided the vital link of communication with the officer on the street.

Officers were directed into occupied park buildings and the Marina District to conduct an orderly evacuation of visitors and residents. When they entered devastated buildings they reported the addresses and number of people entering with them to search. Upon completion they again notified communications. This contributed to establishing the critical list of empty and secured buildings.

## **PLAN DEVELOPMENT**

I arrived at the field office and met with the duty supervisor. We agreed to split responsibilities. The duty

officer would handle the street operations, and I the organization of equipment, communications and manpower. Unable to locate the emergency plan, and having experience in crime scene search, I decided that it could be handled as a large crime scene. The day shift, which was just going off duty, returned to work and assisted. These officers doubled the available manpower. Because of the traffic problems trail bikes were used to get into the effected residential areas. A central command post was set up a short distance from the communications center. One officer was assigned to building security, and as the contact person with the public who came to the Field Office seeking support. A National Park Service ranger was assigned to work with the police dispatchers to coordinate the many requests that were coming in over several radio channels. Food, water, first aid, portable generators and other supplies were gathered from outlying park areas and rushed to the field office for our use. We set up a shelter for the homeless in a park building. Securing gasoline became an obstacle. A truck was procured, along with two 50 gallon drums. At one point a gas station was "seized" so that we could secure fuel for the generators and vehicles.

## **PSYCHOLOGICAL STRESSES**

The impact on supervisors and officers was evident from the beginning, especially for those who were in the city and rode the quake. The devastation, the helplessness, and the sight of death took its toll on our officers. With every after shock the tension increased. Officers had to be forced to take breaks and find quiet areas. Each person had to take the time to regroup. Many days and weeks later the stress was still apparent in some of us.

We faced many problems that night that were never addressed in any contingency plan.

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# THE CLASSIFICATION AND USES OF VOLUNTEERS AT A DISASTER

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The need and utilization of volunteers at a disaster is a logical consideration regardless of the size of the affected agency and disaster. Pre-planning through the use of a disaster plan should include the anticipated use of a wide spectrum of skilled volunteers in positions that can become a resourceful asset to the working of a disaster. The basic underlying concept is to classify your volunteer resources, which can include both sworn (commissioned) and non-sworn (police/government civilian employees) personnel along with the civilian population, in job-related functions during the working of a disaster that benefits both the mission and the organization.

The defining of volunteers for the purpose in this concept are those individuals who give of their own free will for services or duty without benefit of compensation.

## APPLICATION OF THE CLASSIFICATION AND USES OF VOLUNTEERS

The use of a volunteer coordinator/manager or reserve liaison supervisor to coordinate the use of volunteers is imperative because if not organized, the volunteers may do more damage than good (Wilson, M. personal communication). This, for the most part, can be eliminated through a brief interview and classification of the volunteers' skills at a disaster. A simple skills and abilities form that lists the volunteer's name and classification is necessary. The classification and suggested uses are as follows:

**Class 1 Volunteer-sworn personnel**—Sworn off-duty personnel, sworn reserve/auxiliary/posse personnel with full or limited Peace Officer certification, recently retired personnel whose certification could be easily re-activated and recruits in academy training. These volunteers can be used to provide scene security and basic police services at the disaster.

**Class 2 Volunteer-non-sworn police personnel**—Civilian police employees, technicians, telecommunicators, police aids and police explorer scouts. The list can also include other city/county/state employees. These volunteers can be used to provide logistics and supply accountability, information dissemination, recording and monitoring of various disaster areas.

**Class 3 Volunteer-civilian professionals**—Medically-trained volunteers such as doctors (active and retired), nurses, paramedics, psychologists, social workers, architects and engineers. This group of volunteers can provide on-scene medical and technical assistance and advisement.

**Class 4 Volunteer-civic community groups**—Kiwanis, Rotary, etc., that can assist in transportation, lodging and supply dissemination.

**Class 5 Volunteer-general civilian volunteer**—General public, civic-minded individuals, who have general skills but not in the above-mentioned groups. These volunteers can furnish clerical to manual labor, child care to construction.

## CONCLUSION

The necessity to having a prepared system for volunteers at the scene of a disaster was noted by R. Navarro (personal communication) from an observation he made about the San Francisco earthquake. He indicated that volunteers will turn out by the hundreds and that a plan is needed that will organize the work force more efficiently. Confusion can only lead to uncontrolled chaos — you must have a plan that makes the best use of people when you least expect them to come forth and volunteer their time and skills.

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# IDENTIFICATION OF VICTIMS OF CONFLAGRATION THROUGH COOPERATION BETWEEN FORENSIC DENTISTRY AND FORENSIC ANTHROPOLOGY

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The identification of bodies burned beyond recognition has long been the duty of the forensic odontologist. In remains that have been exposed to high temperature fires for an extended period of time the comparison of dental evidence recovered from the scene with the dental records of putative victims often becomes the only available method of establishing positive identification.

Some of the petrochemical manufacturing and refining plants located in the industrial corridor along the Mississippi River in south Louisiana have been the scenes of several serious explosions and fires over the past few years. Drilling and production platforms in the off-shore waters and marshes as well as gas pipelines have ignited and burned. In addition, the transportation of raw materials and products associated with this industry, has resulted in traffic accidents with high-temperature, long-burning fires. In some of these blazes there have been multiple deaths.

The temperature of a gasoline fire in still air can reach 1093°C. The National Fire Protection Association (1972) states that piled wreckage can alter the air flow creating a chimney effect elevating the temperature above this. The human skeleton when exposed to extreme heat may be reduced to ashed fragments. These pieces often retain a large degree of the anatomic configuration present before burning. However, they are reduced in size and are extremely fragile and may be easily overlooked or inadvertently destroyed by an untrained person.

Teeth exposed to such temperatures undergo structural and morphologic changes as noted in Table 1 which is adapted from Harvey (1976). At temperatures beyond 1000°C a tooth can be rendered unrecognizable even if viewed by an SEM according to Harsanyi (1975). An unpublished report by Bell (1987) stated that the roots of teeth which were experimentally exposed to temperatures of about 1100°C exhibited a shrinkage of 20%. At

such temperatures the clinical crown of the tooth is nearly always destroyed, therefore the dental restorations and other characteristics normally relied upon to prove the identification cannot be used.

The use of proper recovery technique, directed by persons such as forensic anthropologists knowledgeable in specimen recognition and preservation, is essential. The dental remains are extremely fragile and must be carefully searched for and preserved for analysis. Richie (1987) in an unpublished report suggested that special radiographic techniques be employed, photographs be taken, and the remaining tooth fragments be stabilized with cyanoacrylate prior to further examination. Morgan (1990) presented a case in which large amounts of ash were radiographed on large plates. Suspected fragments

**Table 1. TEMPERATURE FINDINGS (C°)**

100	Enamel rods and dentin altered, enamel whiter (mottled), root light yellow.
200	Enamel rods lose structure, crown and root orange
300	Cracks in enamel, crown yellow-brown, roots dark brown or destroyed, carbonization of Tomes fibers.
400	Crowns of healthy teeth split, crowns brown-black, multidirectional cracks in crown, cracks in root and dentin almost to pulp.
500	Crown and root grey-white, multiple cracks, enamel exfoliates particularly facial and lingual.
640	Heat of household furnace. Reduction in volume of root, carbonization of dentin.
800	Silver amalgam may reach this temperature intact.
915	Cremation temperature USA.
915-1090	Gold alloys melt, synthetic porcelain fuses.
1090	Porcelain may survive.
1100	Dentin and enamel retain their narrow canals.
1200	Cremation temperature UK.

Studies by Komori, Basauri, Luntz.

Cited in Harvey, Warren; Dental Identification and Forensic Odontology, Henry Kimpton Publishers, London, 1976.

of teeth or restorative materials were identified on the film and then located in the undisturbed debris. The authors recommend that trained forensic anthropologists screen and visually search all of the ashes for tooth and bone fragments.

Comparison of incinerated dental remains with the antemortem dental records is more difficult than in a typical identification. Since the dental examiner must rely upon root and bone morphology as visualized through radiographs to complete the task it is vital that every possible fragment be recovered. One never knows which fragments will be the ones which may clinch the identification. In addition, by matching the recovered root fragments with their anatomical position, the dental examiner can prove that there was only a single decedent and that commingling or an unexpected or unreported death did not occur.

Photographs will document recent cases of cooperation between the various law enforcement agencies, coroner's offices, and forensic experts which resulted in the successful recovery and identification of bodies in southeastern Louisiana.

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# EXPLORATORY DESIGN FOR A COMPUTERIZED DISASTER INFORMATION MANAGEMENT SYSTEM

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Recovery from a mass disaster requires energy and information. Our search for existing models of producing and managing the information associated with disasters has produced few indications of prior efforts to use computers to deal comprehensively with information handling as an element of disaster response. The CAPMI system, for example, deals only with identification of remains. We explored ways that appropriate software might be used with a suitable computer to expedite the transition back to order following a disaster.

A disaster information management program should be flexible. In designing the software, we identified similarities in different types of accidents. We used spatial expanse, enclosure, number and dispersion of victims, and the condition of remains to distinguish and group incidents. Generalized checklists and protocols can be stored in the computer, quickly modified for actual use and reproduced for distribution at the scene.

Because disasters are unexpected and infrequent, a certain amount of confusion by responders is inevitable. The final software design must have an intuitive and helpful user interface. The user should be aided with abundant, context-sensitive help screens and be able to tell what options are available, where he/she is in the program and how to move back and forth between screens. Automatic backup and redundancy prevent loss of data either from power interruption or user error. A Windows-type user interface was developed. Tasks were kept as icons on the screen and activated as needed. Several lists or views of data can be seen simultaneously and text and graphics can be mixed.

We identified four information stages: mapping, input, analysis and reporting.

The first stage of information collection involves obtaining and recording spatial information such as the

location of the wreckage, the distribution of survivors and victims, access to the scene, scale and topography. Maps may be entered by digitizer or scanner, retrieved from a database, converted from video image or sketched by hand. Maps provide bases for storing and indexing other information.

The second stage consists of entering data. As work progresses, information becomes more textual. Passenger manifests, antemortem records and descriptions, post-mortem locational and anatomical data such as dental traits will be entered. In addition, lists of workers and their assignments are recorded. As help arrives, abilities and equipment can be catalogued along with radio, and mobile phone numbers. Any of this information can be selected and printed for use by those at the scene.

The third stage is analysis. Information about the incident such as speed, angle of impact, and direction may allow the computer to predict search areas for remains of unidentified victims. The computer will also search and organize data in order to eliminate impossible matches thereby making preliminary assessments of possible matches. Experts will make the final decisions on identity.

In the fourth stage the focus shifts to reporting. The software provides the formats for retrieval of many types of data. The operator may also call up any data in a desired form. To facilitate follow-up and review, steps in the analytical procedure are saved for later evaluation and final reporting.

This system allows the collection, comparison, analysis and conservation of information. It promotes handling of information about the scene, the remains of victims and the personnel involved in the operation.

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## MANAGING FORENSIC INFORMATION IN MASS CASUALTY DISASTERS

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During a mass casualty investigation, the ultimate goal is to identify victims in as timely a fashion as will not compromise accuracy. Attaining this goal is made more difficult by the huge volume of data that must be managed. As antemortem records are received and initial postmortem examinations are recorded, investigators, some with modest experience and training, are faced with an intimidating quantity of raw data. Having to organize the records by hand unnecessarily lengthens the identification process.

The objective of our research has been to construct computer programs in managing the large volume of forensic information. We have presented our earlier efforts towards this goal (Mertz and Purtilo 1986). Since then we have constructed a new program to incorporate our experiences with the earlier versions. As a result of our evaluation and tuning, we have produced FORENSIC, a computer program to assist forensic dentists bring order to the mass of raw data found at mass casualty disasters.

Running on IBM personal computers and their clones, FORENSIC relieves investigators of the tedious process of combing through records time and time again by hand. Using our program, all dental records can be centralized and easily accessed. FORENSIC provides a simple searching capability that suggests matches between antemortem and postmortem records; this allows investigators to spend their time sorting out small numbers of likely matches, rather than having waded through a large number of obviously irrelevant records.

Each record in FORENSIC is assigned a unique case number that can be used to label associated physical evidence. The program stores the name (where known), and simple characteristics such as race, blood type, sex and age. Dental information organized by FORENSIC includes presence or absence of each tooth, and whether it is replaced by a fixed bridge or removable partial. When the tooth is present, FORENSIC lists unattended caries or presence (and type) of fillings for each of five surfaces of the tooth. Previous versions of FORENSIC utilized other information such as root canals, shovel-shaped incisors and mottled enamel. However, our experience has been that these characteristics add little to the program's ability to suggest matches between antemortem

and postmortem records; moreover, these characteristics present users with a significantly more complex program to use, with extra opportunity to introduce error. Our decision in the current version of FORENSIC was to keep it simple.

In order to suggest possible identifications, FORENSIC compares each record with all available records. Each comparison results in a rank ordering of likely identifications, based upon a weighted sum of how many dental characteristics match. The weights in this sum have been determined experimentally (it is easy to see why weights must be used, since, for example, the appearance of a gold crown in a pair of records is clearly more important than a matching composite filling). The ranking also lists a confidence factor, that is, an indication of how much information the match was based upon. To see why this is important, consider the record for a small fragmented (say teeth 1 through 3, the right rear uppers). Without other information, this fragment will closely match a large number of other records so any identification based on this output would not be of great value to an investigator. However, FORENSIC would list an identification based on only three teeth as being of low confidence; therefore a user would know to simply move on to other records, saving this one for consideration later after more of the easier identifications have reduced the search space.

No computer program alone can manage the forensic information from an accident, as a computer program is only one tool among many that investigators may use. FORENSIC can only produce accurate results when investigators implement sound practices for both collecting and then interpreting the data. Therefore an important aspect of our research is to consider not just the computer program, but the entire methodology wherein the program would be used.

This entails reducing the number of points where information must be transcribed manually (for example, collection of antemortem medical records by telephone), in order to minimize opportunities for introduction of errors. It also entails increasing the number of ways that data can be checked independently (for example, requiring that telephone records be followed up with paper copy by courier), so that inconsistencies are more likely

to be exposed. Most important of all, information management procedures must be simple enough so that all investigators will use them. The basic steps must be easily taught to support staff that assist at an accident site; the procedures must be resilient in the face of errors that inevitably accumulate in raw data.

As stated earlier, FORENSIC does not store all dental characteristics. However, we hypothesize that additional anthropological information would prove to be useful to investigators. Moreover, we believe the comparison techniques that we developed for dental parameters can be applied to general anthropological information. Therefore, in the future we plan to add such

parameters into the program, and then extend our searching algorithm to include them. Examples of such parameters are hair and eye color, missing anatomical parts, handedness, implanted prosthesis or bone plates and orthopedic surgery.

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# WISCONSIN'S MASS DISASTER IDENTIFICATION TEAM; ITS EVOLUTION

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Recognizing the potential for a major disaster and aware of the key role dental identification can play in the investigation, the medical examiner requested that a team of dentists be organized and trained for just such an eventuality. We thought that if a major metropolitan area the size of Milwaukee County lacked this resource, then none of the other counties would be likely to have it either. Without a trained team, the coroner/medical examiner would have to rely on a hurriedly collected group of volunteers who would be unprepared for what they might encounter. It would be impractical, if not impossible, to establish and maintain a dental identification team in each of the counties in the state. If a team was to be organized for Milwaukee County, why couldn't the idea be expanded into one team, thoroughly trained and equipped, for the entire state?

## METHODS AND MATERIALS

To determine the availability and interest level of Wisconsin dentists, an orientation program was held in conjunction with the annual meeting of the Wisconsin Dental Association in May 1983. An extensive program subjected those attending, not only to the technical aspects of the identification process, but also to the grim, human devastation. We felt that exposure to reality would eliminate those with only a casual interest and dispel any idea that a disaster investigation is an adventure.

In an overwhelming response, and in spite of the adversities demonstrated, over seventy dentists expressed interest in participation in a disaster identification team. A protocol detailing the organization and responsibilities of the team was developed. Dr. Gary Bell of Seattle, Washington graciously offered his protocol as a model. A grant from the State of Wisconsin was obtained to purchase field kits and basic supplies for each of the seven emergency government districts. The location and emergency availability of larger pieces of equipment such as portable dental x-ray machines and automatic film processors was ascertained, and a check list was developed.

Through the cooperation of the Wisconsin Department of Justice, Marquette University School of Dentistry and the Wisconsin Dental Association, a two day seminar was developed and held in January 1984. At this

time, hands on experience began with laboratory exercises in the identification of casualties of a mock disaster.

Based upon this initial training session a computerized roster of members was developed with listings according to county of residence, emergency government area, experience and training, and alphabetically.

In September 1985, the wisdom of this preparation was graphically demonstrated when Milwaukee suffered its first major air disaster. Directly as a result of the efforts expended in the development of the team, it was immediately able to respond. Working closely with the FBI Disaster Squad, the team completed its investigation within 72 hours and the last casualty (awaiting dental records from overseas) was positively identified within seven days.

The following July, the State of Wisconsin, Department of Administration, Division of Emergency Government, integrated this valuable resource into its disaster plan.

Subsequent training sessions have been devoted to experiences in laying out a grid, photographing the site and recovering the casualties. Others have been devoted to familiarization and training in computer assisted post-mortem identification programs and stress management.

Because of periodic changes, for example, telephone number, addresses, or level of interest in participation, annual availability telephone calls or questionnaires are used to keep our data base current.

As development of other dental identification teams occurred in the surrounding states and metropolitan areas of Minnesota, Illinois and Indiana, the adjacent availability of highly trained dental identification personnel, has resulted in mutual aid agreements in case of a megadisaster.

## CONCLUSION

As a result of preplanning, the team was able to accomplish its mission in a highly expeditious manner, clearly demonstrating that being prepared is sound advice. Further recognition of the value of this resource was demonstrated in July 1986 by the adoption and integration of the dental identification team by the Division of Emergency Government in its Information and Guidance Memo 7/2/86.

Annual ongoing training continues for the team leaders and members to keep them abreast of current development, to practice their skills and to maintain their high level of interest and enthusiasm.

From our experience, it is suggested that rather than duplicate a team for every area of a state, or to have to recreate one whenever the need arises, it is far more

advantageous to devote the available resources to establishing and maintaining a state-wide team with members widely distributed throughout the state. Highly trained leaders, who can be flown to the site to guide the investigation, are available from the major metropolitan areas where they are active in the field of dental identification.

## MULTIAGENCY TRAINING EXERCISE

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The Medical Examiner's Office, District Six/Pinellas County Forensic Laboratory (MEO), Pinellas County Sheriff's Office (PCSO) and MacDill Air Force Base staged a mock crash involving a military aircraft on April 14, 1988. The exercise was staged to test the mass disaster plans of each agency and to see how complicated jurisdictional conflicts would be resolved. This was the first drill in which actual mass disaster scene processing was performed by the MEO and PCSO. It was also the first time in several years MacDill staged a drill at a civilian site.

Separate command posts were set up for each agency. A joint site command post was also established for agency commanders to confer and quickly resolve problems.

Coordination of site responsibilities and integration of three separate disaster plans had to be decided upon at the scene. All commanders held a brief meeting to determine the plan of action to be followed by all agencies involved. The traditional grid search and recovery method proposed by the MEO and PCSO was determined to be inefficient when compared to the line search and recovery method proposed and utilized by the military. Civil engineers from MacDill surveyed and sketched the scene and assumed responsibility for recovery of aircraft parts. MacDill conducted an initial briefing for search teams, taking a few extra minutes to teach MEO and PCSO personnel the basics of their method. Two persons were

assigned to sequentially number and note each item flagged by these search teams. The MEO took responsibility for all body parts and personal effects with the assistance of the PCSO. The entire exercise was photographed and video taped by the PCSO.

Twists were incorporated into the exercise with different scenarios being added during on-site activities. This caused several body recounts. For example, a distraught mother tried to gain access to the site, claiming her small child had been fishing in the area. After a review of the body count to that point, which did include the body of a small boy, it was determined there was a conflict with the military passenger manifest. The conclusion was that the passenger manifest was in error due to unregistered passengers. A small briefcase handcuffed to a dismembered arm was found to contain classified material. Control of this briefcase was assumed by the military.

Although this was a controlled situation, it pointed out minor flaws in each of the agency's plans. These flaws were easily corrected at the site.

All agencies demonstrated the ability to cooperate with and assist each other. The commanders from each respective agency concluded it was an excellent learning experience. The drill showed the importance of testing and exercising mass disaster plans before they are needed so that one has a better chance to react comfortably in an uncontrolled situation.

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## **CRIME SCENE AND MASS DISASTER ASSIGNMENT CHECK SHEETS**

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Rohnert Park, California

Agencies may not have the luxury of having all their equipment and materials prepositioned for immediate deployment to an extensive crime scene or disaster. Usually, when a call is received the person that is to respond to the location must go through a mental process of trying to remember what equipment is available and what will be necessary for this one assignment.

As a more complicated major crime investigation evolves, there is the necessity of adding investigators to the team. Immediate follow-up of leads and suspects is important to case adjudication. These assignments need to be tracked for completion and responsibilities need to be identified.

Forms have helped accomplish the needs of those assigned. The forms in Figure 1 are for the crime scene

investigators and are employed both prior to leaving for the assignments and after arrival. The major crime investigators forms (Figure 2) are used primarily by the coordinating officer to make sure all aspects of the death are adequately checked.

The death scene check list (Figure 3) provides information and consistency. In all cases of death investigations by my agency, officers utilize this form and then attach it to other supporting reports.

Applying some type of check list at a large incident minimizes confusion, brings the proper resources to bear on the problem at hand, and eliminates mental confusion. Collaboration with those in your agency can provide you with a customized recording and reporting system.

HOMICIDE CRIME SCENE INVESTIGATION			
<b>I. ARRIVAL AT SCENE</b>			
Suspect in Custody?	Admission Made?	Who By?	
Cordon	Time		
NAME		ID #	TIME
Major Crimes Personnel at Scene			
Bureau of Criminalistics Personnel			
Support Units at Scene <input type="checkbox"/> # of Personnel			
Coordinator			
Coroner (1st Response)			
(2nd Response)			
Pathologist			
Crime Lab Personnel			
Misc. Additional Support			

HOMICIDE CRIME SCENE INVESTIGATION			
<b>II. ASSIGNMENTS</b>			
DETECTIVES	NAME	ID #	TIME
Primary Investigator			
Assisting Investigator			
Coordinating Investigator			
Canvassing Investigators			
Other (Include Officer Assigned to Interview Suspect - May be Primary Investigator)			
<b>BUREAU OF CRIMINALISTICS</b>			
Primary CSI			
Photographer(s)			
Vehicles/Licenses			
Latent Prints			
Evidence Collection			
<b>III. CRIME SCENE EXAMINATION - INTERIOR SCENE (Structure)</b>			
Description of Structure:			
Description of Location:			

Figure 1. Homicide Crime Scene investigation forms illustrating 2 of many pages.



**RONHERT PARK DEPARTMENT OF PUBLIC SAFETY  
UNEXPLAINED DEATH SCENE CHECK LIST**

Report No. \_\_\_\_\_

Date/Time \_\_\_\_\_

NAME OF DECEASED: \_\_\_\_\_  
Last
First
Middle

ADDRESS \_\_\_\_\_ PHONE NO. \_\_\_\_\_

D.O.B. \_\_\_\_\_ AGE \_\_\_\_\_ S.S.# \_\_\_\_\_ RACE \_\_\_\_\_ SEX \_\_\_\_\_

NAME OF DOCTOR \_\_\_\_\_ ADDRESS \_\_\_\_\_

CITY \_\_\_\_\_ PHONE NO. \_\_\_\_\_ LAST SEEN \_\_\_\_\_

HEALTH PROBLEMS OF DECEASED: \_\_\_\_\_

LAST CONTACT WITH DECEASED: Date \_\_\_\_\_ Time (approx) \_\_\_\_\_

Name/Address of Contact \_\_\_\_\_

Phone Number \_\_\_\_\_

Type of Contact: Phone \_\_\_\_\_ In person \_\_\_\_\_ other \_\_\_\_\_

NEXT OF KIN: Name \_\_\_\_\_

Address \_\_\_\_\_ Phone # \_\_\_\_\_

FUNERAL HOME REQUESTED: \_\_\_\_\_

POLICE NOTIFIED BY: Name \_\_\_\_\_

Address \_\_\_\_\_ Phone # \_\_\_\_\_

Date \_\_\_\_\_ Time \_\_\_\_\_ Relation \_\_\_\_\_

DECEASED FOUND: Date \_\_\_\_\_ Time \_\_\_\_\_

Location: Home \_\_\_\_\_ Apartment \_\_\_\_\_ Townhouse \_\_\_\_\_ Other(describe) \_\_\_\_\_

Entrance by: Key \_\_\_\_\_ Forcing Door \_\_\_\_\_ Cutting Chain \_\_\_\_\_ Other(describe) \_\_\_\_\_

Type of lock on door: \_\_\_\_\_

Condition of other doors and windows: Open \_\_\_\_\_ Closed \_\_\_\_\_ Locked \_\_\_\_\_ Unlocked \_\_\_\_\_

BODY FOUND: Bedroom \_\_\_\_\_ Living room \_\_\_\_\_ Dining Room \_\_\_\_\_ Kitchen \_\_\_\_\_ Other \_\_\_\_\_

Location in room: \_\_\_\_\_

Position of body: on back \_\_\_\_\_ face down \_\_\_\_\_ other \_\_\_\_\_

CONDITION OF BODY: Fully clothed \_\_\_\_\_ Partially clothed \_\_\_\_\_ unclothed \_\_\_\_\_

Preservation: Well preserved \_\_\_\_\_ Decomposed \_\_\_\_\_

Estimated Rigor: Complete \_\_\_\_\_ Head \_\_\_\_\_ Arms \_\_\_\_\_ Legs \_\_\_\_\_

Lividity: Front \_\_\_\_\_ Back \_\_\_\_\_ legs \_\_\_\_\_ Arms \_\_\_\_\_ Other \_\_\_\_\_

Color: \_\_\_\_\_ Blood: Absent \_\_\_\_\_ Present \_\_\_\_\_ Location \_\_\_\_\_

Figure 3. Unexplained Death Scene Check List forms.

# EVALUATION OF MASS FATALITIES IN DEEP UNDERGROUND COAL MINES

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The deep underground coal mine, with perhaps the exception of marine transportation, is inherently and intrinsically the most hazardous working environment in the U. S. (Knight 1977). Deaths in underground coal miners generally occur by five groups of mechanisms, including roof falls, electrocution, underground machinery, explosions and pure asphyxia. Multiple simultaneous fatalities are usually seen only with roof falls and explosions.

Kentucky, as one of the leading underground coal producing states, has had vast experience dealing with fatally injured miners and "killer" coal mines. We reviewed all deep underground coal mine deaths in the State of Kentucky over a ten year period, from 1980 through 1989, in order to give an overall picture of the frequencies of the various mechanisms of death and a schema of postmortem scene and fatality evaluation.

## RESULTS

The results of this study appear in Table 1. There were a total of 192 deep underground coal miners killed in 157 incidents during the ten year period studied. Over half (51%) of the incidents were roof falls, accounting for 89 (46%) of the deaths, mostly in roof bolters and their helpers. Machinery and haulage accidents accounted for the next most common incident, of which 43 (27%) occurred, killing 43 miners (22% of total deaths). Nine explosions (6% of incidents) due to coal dust, shot firing, and methane, were responsible for 31 (16%) of the deaths. Three of the explosions caused 25 of these deaths. Electrocution of individuals was implicated in 23 deaths (12%) and made up 15% of the incidents. Pure asphyxia due to lack of oxygen resulted in six deaths (3%) during two incidents (1%).

## CONCLUSION

The majority of deep underground coal mining deaths in Kentucky over the ten year study period were due to roof falls, followed in descending order by machinery/haulage accidents, explosions, electrocutions and

asphyxia. Multiple simultaneous deaths were seen only in explosions and roof falls, occurring in three and four of these incidents, respectively.

Knowledge of inherent dangers within the underground coal mine is imperative for safe and effective investigation of deaths occurring there. Without this knowledge, the investigator enters at his own risk into a known "killer" coal mine. Finally, if you do not know and can not ask someone who does, do not go.

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**Table 1. DEEP UNDERGROUND COAL MINE  
DEATHS IN KENTUCKY 1980-1989\***

Year	Roof Fall	Machinery	Explosion	Electrocution	Asphyxia
1980	7 (7)	4 (4)	1 (1)	3 (3)	0
1981	8 (8)	8 (8)	3 (10)	4 (4)	1 (3)
1982	12 (14)	5 (5)	1 (7)	3 (3)	0
1983	4 (4)	2 (2)	0	2 (2)	0
1984	16 (20)	8 (8)	0	1 (1)	0
1985	7 (8)	1 (1)	0	1 (1)	1 (3)
1986	4 (4)	2 (2)	1 (1)	5 (5)	0
1987	15 (15)	4 (4)	0	1 (1)	0
1988	1 (1)	4 (4)	2 (2)	1 (1)	0
1989	6 (8)	5 (5)	1 (10)	2 (2)	0
Total	80 (89)	43 (43)	9 (31)	32 (23)	2 (6)
	51% (46%)	27% (22%)	6% (16%)	15% (12%)	1% (3%)

\* 157 incidents occurred with 192 deaths. The number on the left in each column is the number of incidents; the number in parentheses is the number of deaths.

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## MUTUAL AID AMONG MID-CONTINENT ODONTOLOGISTS

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Several years ago, as an outgrowth of discussions at an annual meeting of the American Academy of Forensic Sciences, a meeting was held in Chicago to establish a mutual aid network of board certified forensic odontologists in the mid-continent region of the U. S. A group was formed and is called the Mid-Continent Odontologists' Mutual Aid Network. The area this group serves is illustrated in Figure 1. Each member of this network has the primary responsibility for forensic odontology in a major metropolitan medical examiner/coroner's facility as well as directing a county region, or state-wide dental identification team.

In the event of a mass disaster of extreme proportions, where a number of local volunteer dentists without formal forensic training might be needed to supplement existing trained team members to complete the oral autopsies and correlation of the dental records, a mechanism is now in place so that additional experienced supervisory personnel are available if needed. Each of these network member American Board of Forensic

Odontology Diplomates has agreed to be available for such mutual aid assistance.

While the two most recent serious domestic airline accidents have had fewer than 200 casualties and were efficiently handled by the local jurisdiction, it is anticipated that this mutual aid system would be necessary only in cases with greater than 300 casualties. Dental records remain today as the most universal method for making identification of the average private citizen involved as a victim in a common carrier accident or terrorist act.

Given the climate today for terrorist acts, as well as larger capacity aircraft, higher speed trains and highways, and high-rise buildings with daytime populations in the tens of thousands, a disaster of catastrophic proportions could severely tax local dental resources necessary to make timely identification of the victims. Under this system it would be possible to run round-the-clock shifts of dentists with highly experienced supervision to assist law enforcement, as well as comforting the next of kin by making rapid repatriation of the victims possible.

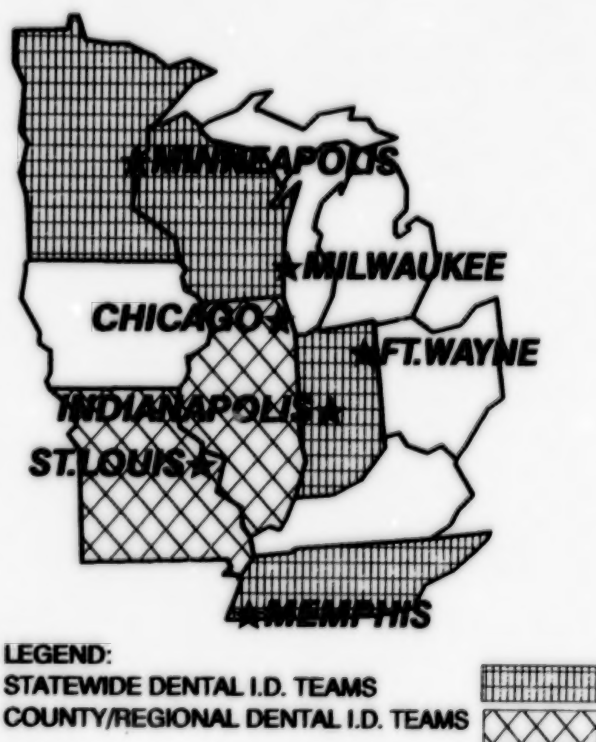


Figure 1. Mid-Continent Odontologists' Mutual Aid Network.

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# LASER LATENT FINGERPRINT DETECTION ON STRONGLY FLUORESCENT SURFACES BY TIME-RESOLVED IMAGING

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With the advent of Automated Fingerprint Identification System (AFIS), fingerprint evidence is assuming greater importance than ever because cold searching is now possible. In terms of identification of unknown latent prints, the success of AFIS clearly is linked to the sensitivity with which latent prints can be detected. It is thus especially timely to develop better techniques for such detection. By now routine laser fingerprint detection procedures such as staining with rhodamine 6G after cyanoacrylate ester fuming for smooth surfaces and ninhydrin/zinc chloride for porous surfaces have proven effective and highly sensitive. On strongly fluorescent surfaces, they tend to fail, however. To remedy this shortcoming, a second-generation laser technique that involves time-resolved luminescence imaging is currently under development. The concept of time-resolved fingerprint detection was first reported in 1979 (Menzel 1979).

## INSTRUMENTATION

In the system operating in our laboratory, the laser light incident on the article is chopped via a mechanical light chopper or electro-optic modulator. The light then passes through an optical fiber as usual to illuminate the article. The latent print, treated such that it yields a luminescence of lifetime much longer than that of the background fluorescence, is detected by means of a gateable microchannel plate image intensifier. The intensifier is synchronized with the chopping frequency such that it turns on shortly after laser pulse cessation. By that time, the background fluorescence has decayed already, whereas substantial fingerprint luminescence is still present. The intensifier turns off before onset of the next laser pulse and the imaging sequence is repeated over many cycles. Fingerprints are visible on the phosphor screen of the intensifier and are photographed (Menzel and Mitchell 1990). We are currently constructing a more elaborate and sensitive system, shown in Figure 1, which involves a gateable digital camera interfaced to a desk-top personal computer with image processing and hard-copy output capability. We envision eventual direct interfacing to AFIS.

## FINGERPRINT TREATMENTS

The crux of the time-resolved technique is the treatment of fingerprints to achieve intense and long-lived emission. To date, we have primarily focused to tris (2,2' - bipyridyl) ruthenium (II) chloride hexahydrate and similar ruthenium complexes for detection of latent prints on smooth surfaces. These display intense and long-lived charge transfer phosphorescence. The complexes can be incorporated into dusting powders and they preferentially stain fingerprints (Menzel 1988). For porous surfaces, ninhydrin analogs are used in concert with chlorides of the rare earths  $Tb^{3+}$  or  $Eu^{3+}$ , in a manner akin to the customary ninhydrin/ $ZnCl_2$  treatment. Ligand-to-rare earth intramolecular energy transfer leads to enhanced and long-lived rare earth emission (Menzel 1989; Menzel and Mitchell 1990).

The treatment for smooth surfaces requires blue-green excitation whereas the treatment for porous surfaces require near-ultraviolet excitation, both obtainable from argon ion lasers. The requisite wavelength switching is cumbersome from a practicality perspective. Accordingly, we are investigating alternative staining dyes and reagents the permit excitation at the same wavelength. We have identified the staining dye bis(triphenylphosphine) 2,9 -dimethyl, 1, 10-phen-

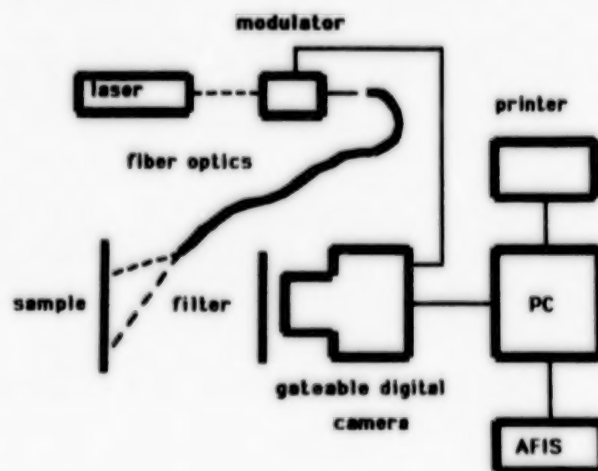


Figure 1. Time-resolved imaging system for laser fingerprint detection.

anthroline copper (I), with  $\text{BF}_4^-$  as the anion and is shown in Figure 2. It functions much like the above mentioned ruthenium compounds and lends itself to new-UV excitation. We are currently investigating similar copper complexes to optimize fingerprint detectability. We are also examining a range of ninhydrin analog/rare earth combinations with the aim of finding a treatment suitable to blue-green excitation.

#### ACKNOWLEDGEMENT

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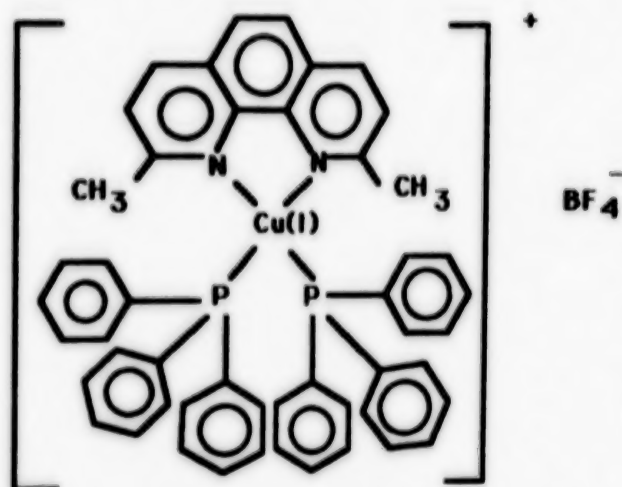


Figure 2. Structure of bis (triphenylphosphine) 2,9-dimethyl-1,10-phenanthroline copper (I) tetrafluoroborate.

# **CRIME SCENE DOCUMENTATION THROUGH PHOTOGRAPHS AND SKETCHES INCLUDING "PAINTING WITH LIGHT" TECHNIQUE**

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Sufficient documentation for the purposes of crime scene reconstruction can be accomplished through written reports, photography and sketches. All three techniques are interrelated, that is, a description of each photograph is included in the written report and the position and direction of each photograph is incorporated into the sketch.

The first photograph taken of any crime scene, traffic accident or disaster scene will be an identifier; a card with the case number, location, date and photographer's name. The next series of photographs will be general, overall views of the scene taken in a planned, systematic method. Numbered cones, chalk lines and police personnel should not be in these photographs. Photographs of small areas, individual items and close-up photographs should be taken first without scales, north arrows, numbered cones, magnetic numbers and chalk lines. Then those indicators and identifiers can be placed in the area or next to the object and a photograph taken.

Photographically documenting an outdoor crime scene, traffic accident or disaster scene during the night hours is difficult if the scene is large or spread out. A time exposure may be used but the color balance will be incorrect and significant evidence may be lost in the shadows. In a scene over 50 feet long, one flash from an electronic flash unit is inadequate. A solution to this problem is to use a photographic technique called "painting with light."

The equipment needed includes a camera with manual operations, a tripod, locking cable release, electronic strobe unit and film. The camera may be any size format but must be manually set and focused. An electronic flash unit with a guide number higher than 100 is desirable, although those with guide numbers lower than 100 will work. Film can be black and white or color print or color slide. An extremely high speed film is not needed for this process. Using ASA 64 film can be as effective as ASA 400 film.

Set the camera on the tripod and focus. Set the shutter speed on "B" and the aperture on f/8 or f/11. Attach the cable release to the shutter button, depress and lock it, causing the shutter to open and remain open. Using the detached electronic strobe unit, pace a few steps and flash the light toward the scene. Continue to pace and flash the light, circling the scene. Upon returning to the camera, unlock the cable release, allowing the shutter to close. Repeat the process, varying the number of steps per pace from the first exposure. No special film processing is required.

Because of the variables involved; the speed of the film, the size of the scene, and the guide number of the strobe, the exact number of flashes and the number of steps per pace cannot be stated. Practice and experimentation will produce good results. At any scene, more than one photograph must be done to ensure an adequately exposed scene.

After the film from the crime scene is processed, a contact sheet is made of the photographs and numbers are written below each frame. Descriptions of each frame, as indicated by number, including position, direction and the object depicted in the photograph are written in the report. By numbering the frames on a contact sheet, orders from the investigator or prosecuting attorney can be taken easily. Requests for certain frame numbers can be made instead of trying to describe what the photo depicts.

The physical evidence indicated in the photographs by the numbered cones or magnetic numbers are noted by number in the written report and also correspond to the numbers used in the crime scene sketch. The numbers can be made to correspond to the list of physical evidence collected. The sketch also indicates the number, direction and position of each photograph.

Thoroughness and accuracy in the three areas will provide sufficient information for the future reconstruction and/or presentation of a crime scene and physical evidence for prosecution purposes in court.

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# PHOTOGRAPHIC DOCUMENTATION FOR THE RECONSTRUCTION AND INVESTIGATION OF AN EXPLOSION SCENE

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Techniques and methods of explosion investigation and blast scene reconstruction can be shown photographically. Photographs have genuine applications and authentic limitations in this type of scene reconstruction. Photographic examples can be given to show the difficulty in determining the point of origin of a fire and explosion. Photographs can also illustrate the specific evidence observed at the disaster site. The procedure for the investigation of this type can also be demonstrated photographically.

On May 4, 1988 a substantial explosion at a rocket fuel manufacturing plant in Henderson, Nevada, impacted the entire Las Vegas Valley. Elements from the Criminalistics Bureau of the Las Vegas Metropolitan Police Department were dispatched to assist the Arson, Bomb and Fire Investigation units of the Clark County Fire Department in their examination of this incident.

Photography was used to assist these units in the investigation and reconstruction of this explosion. Specific photographs demonstrate possible points of origin of the fire and explosion. Steam craters, unburned accelerant, damage to metal girders and explosion craters were photographed to support the investigation.

The purpose of explosion scene investigation is to determine what happened and why. There is an attempt to ascertain the type of explosive and origin(s) of the explosion.

Generally the origin or seat of the explosion is the area of the most severe or extreme damage. It may be difficult to locate the seat of an explosion. The areas most like to yield unconsumed explosives are at the seat(s) of the explosion.

Photographs of explosive by-products or residues which remain at scene can help identify the explosive. Unconsumed explosive material may also help. This is particularly true when the explosive involved is a propellant powder (in this case rocket fuel).

Photography should be done immediately. The photographer may need to be protected from chemical and

vapor toxins still present. A protective uniform may be required.

Unconventional thinking for the photographer is necessary. The photographer cannot concentrate just on physical evidence such as metal fragments. Overviews of the entire scene showing areas of the blast and distant damage are necessary for complete explosion scene reconstruction. Photographs may need to be coordinated with a diagram, blueprint or map and aerial photographs.

It is possible that there has been a gas explosion if there is no seat or damage is generalized throughout the area. Gas mains and gas pipes must be located and photographed. A gas explosion is generally a low velocity explosion and items and buildings should be photographed to determine if any pushing effects can be located.

Damage to fragments may give clues to the type of explosion. Metal fragments may demonstrate whether a high or low explosive. Fragments of metal from a low velocity explosion may be scratched or bent along the edges, sometimes thin and sharp. Subliminal formations or scratches which resemble ferns may also be found on non-porous (metal) objects very near the seat.

Photograph any located crater(s). Low velocity explosions will make craters of wide diameter and shallow depth. High-velocity explosives will make craters of small diameter in relation to their depth.

Explosion scene photographs may or may not provide conclusive reconstruction results. In most case accurate conclusions will await laboratory findings. The success of a explosion investigation is to some extent a matter of chance. Photographs may in retrospect never conclusively prove the origin, type of accelerant or category of explosion. However, the photographs will provide a permanent record for investigators to review, give an opinion and reconstruct the explosion site based upon the evidence photographed. A list of general procedures that may be followed appears in Table 1.

**Table 1. GENERAL PROCEDURES THAT MAY BE FOLLOWED FOR PHOTOGRAPHIC DOCUMENTATION.**

- |   |   |
|---|---|
| <ul style="list-style-type: none"><li>• Overall views of explosion site should be taken</li><li>• Determine if gas lines present and photograph</li><li>• Photograph areas to determine a hot spot if fire resulted</li><li>• Locate concrete and photograph for possible steam craters on concrete floors</li><li>• Attempt to find center or seat(s) of explosion or explosions</li><li>• Photograph metal fragments and their relationship to background</li></ul> | <ul style="list-style-type: none"><li>• Photograph cement floors to determine if a steam crater is present</li><li>• Find sublimination on metal which may help determine nature of explosion</li><li>• Composite photographs may help with reconstruction</li><li>• Take photographs of crater show depth and width and relationship to background</li></ul> |
|---|---|

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# IMPLICATIONS OF DRUGS IN DECOMPOSING TISSUES TO THE ESTIMATION OF POSTMORTEM INTERVAL USING INSECT DEVELOPMENTAL PATTERNS

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In response to recent increases in drug-related deaths, studies have been conducted to determine effects of cocaine and heroin in decomposing tissues on the rate of development of Diptera larvae feeding on these tissues.

## MATERIALS AND METHODS

Cocaine was administered to domestic rabbits via cardiac puncture in dosages corresponding to 0.5, 1.0 and 2.0X median lethal dosage, based on Tatum *et al.* (1925). A 4th rabbit was used as control. Rabbits receiving lethal dosages of the drug expired due to the effects of the drug, and the sublethal dosage and control rabbits were sacrificed in a CO<sub>2</sub> chamber. Following death, livers and spleens were excised and exposed to a stock colony of *Boettcherisca peregrina* for larviposition. Following colony initiation, colonies were held at a constant temperature. At 6 hour intervals, 10 larvae from each colony were measured for total length, and, at 24 hour intervals, a sample of 10 larvae from each colony frozen for analyses of drug content. Following completion of larval development, puparia were removed from colonies at each 6 hour sampling period and duration of puparial period and adult emergence recorded.

The same procedure was followed for tests involving heroin, except the dosages were calculated to represent 0.5, 0.75, 1.0, and 2.0X median lethal dosages.

## RESULTS

For larvae reared on cocaine, beginning at hour 36, significant differences were observed in rates of development of larvae from 1.0 and 2.0X median lethal dosage colonies, when compared to larvae from the control and 0.5X median lethal colonies. This difference continued through hour 72. No significant differences were detected among colonies in puparial size, duration or adult emergence (Table 1). Larvae from all colonies, except the control, were positive for cocaine and/or benzoylecgonine after 24 hour. All larvae from colonies on tissues containing heroin showed accelerated rates of growth from hours 10 through 96. Significant differences in puparial size and duration of puparial stage

were observed for colonies feeding on heroin-containing tissues (Table 2). Heroin (as morphine) was first detected in larvae from the 2.0X median lethal dosage colony at hour 24, followed by larvae from the 1.0 and 0.75X colonies at hour 48, and the 0.50X colony at hour 78.

Conclusions: Presence of cocaine or heroin in decomposing tissues significantly accelerates the rate of development of Diptera larvae feeding on them. This acceleration can result in an error of up to 24 hour for cases involving cocaine, and 29 hour for cases involving heroin. There is an additional source of error for cases

**Table 1. PUPARIAL DURATION AND ADULT EMERGENCE FOR COLONIES OF *B. PEREGRINA* REARED ON RABBIT LIVER TISSUE CONTAINING VARYING AMOUNTS OF COCAINE.**

Colony	Total Puparia	Total Adults	% Emerging	$\bar{X}$ Duration Stage (Range)
Control	459	409	89%	255 hrs (234-312)
0.50	445	407	91%	253 hrs (234-300)
1.00	390	359	92%	261 hrs (240-294)
2.00	708	649	91%	252 hrs (228-294)

**Table 2. PUPARIAL DURATION AND ADULT EMERGENCE FOR COLONIES OF *B. PEREGRINA* REARED ON RABBIT LIVER TISSUE CONTAINING VARYING AMOUNTS OF HEROIN.**

Colony	Total Puparia	Total Adults	% Emerging	$\bar{X}$ Duration Stage (Range)*
Control	415	402	89%	253 hrs (246-276) a
0.50	209	198	95%	271 hrs (254-282) b
0.75	338	328	97%	273 hrs (272-282) bc
1.00	150	133	88%	279 hrs (272-312) c
2.00	310	266	89%	291 hrs (288-294) c

\*Figures in a column followed by the same letters are not significantly different by Duncan-Waller multiple range test.

involving heroin, where puparial development may be retarded by 18 to 36 hours. These factors must be considered in estimating postmortem interval for cases involving these drugs. Presence of cocaine or heroin in decomposing tissues may also be demonstrated by analyses of Diptera larvae associated with the remains.

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# GENETIC MARKER ANALYSIS IN HUMAN BONE A POTENTIAL AID IN THE FORENSIC IDENTIFICATION OF HUMAN REMAINS

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Determining the ABO group of a person from skeletal remains can be helpful in identifying victims of crimes and mass disasters, particularly when the number of possible identities is limited and when the remains are insufficient for informative anthropological or odontological analyses. Similarly, the isolation and typing of DNA from bone tissue can assist in the identification of skeletal remains. DNA types could be powerful aids in identification to the extent that DNA identification data bases containing the types of possible victims have been established. But even without data bases, DNA types could aid in the accurate assignment of comingled bone to individuals, such as in mass disaster situations.

Numerous studies have been conducted on bone ABO typing, but none has resulted in a reliable procedure. An extensive series of experiments in our laboratories over the past several years has resulted in the development of a highly reliable method for the ABO typing of bone fragments. Details of this method, preliminary results on its application, and a review of past efforts have been reported (Lee *et al.* 1989).

We have conducted ABH grouping tests on a series of bone fragments from 88 different individuals, specimens of all of which were exposed to three different temperatures under both dry and humid conditions, to

dry and moist soil, and to burial in the ground outdoors, and sampled over a period of 9 months. Bone fragments were cleaned and prepared for grouping tests or DNA isolation following the procedure outlined in Figure 1. Absorption-elution (AE) was performed in tubes following the procedure of Gaensslen and Lee (1984) and Gaensslen *et al.* (1985). Two-dimensional absorption-inhibition (2DAI) was performed as described by Lee *et al.* (1988) using three selected dilutions of antisera or anti-H lectin.

In all, 1,534 separate AE and 2DAI tests were performed. Results are shown in Table 1. The key to the reliability of the combination AE/2DAI procedure lies in the interpretation of results. A blood group was conclusively assigned only to specimens that yielded concordant results by the two independent methods (Figure 1). An AE result was accepted for an antigen if 1+ or stronger agglutination was obtained with the eluate. A 2DAI result was accepted if 1st dimension agglutination results were --- or +---, or if the titration score for a specimen 2D test were reduced by 25 relative to an uninhibited control (see Gaensslen *et al.* 1985 for scoring system). AE testing alone generally yielded a higher percentage of correct results than did 2DAI alone, and as expected, more incorrect results were obtained in separate AE and 2DAI testing from specimens kept in soil or

**Table 1. SUMMARY OF ABO TYPING TESTS IN HUMAN BONE TISSUE**

METHOD		TOTAL N(%)	TOTAL - SW N(%)	TOTAL - SW - G N(%)
ELUTION	Correct	1,003 (65.4)	924 (69.5)	827 (71.4)
	Incorrect	471 (30.7)	356 (26.8)	293 (25.3)
	INC / NR	60 (3.9)	49 (3.7)	38 (3.3)
2D INHIBITION	Correct	675 (44.0)	618 (46.5)	568 (49.1)
	Incorrect	402 (26.2)	308 (23.2)	257 (22.2)
	NAD / NR	457 (29.8)	403 (30.3)	333 (28.8)
COMBINATION	Correct	490 (31.9)	464 (34.9)	439 (37.9)
	Incorrect	9 (0.6)	3 (0.2)	2 (0.2)
	NC / NR	1,035 (67.5)	862 (64.9)	717 (61.9)

N(%): the absolute number, followed by the percentage of total in parentheses; SW: wet soil; G: ground; the TOTAL - SW column shows all results except those for samples in wet soil; the TOTAL - SW - G column shows all results except those for samples in wet soil or buried in the ground; INC: inconclusive; NR: no result; NAD: no antigens detected; NC: nonconcordant (elution and inhibition results not concordant for the same specimen)

buried outside (Figures 2, 3 and Table 1). Analysis of actual ABO group distribution in specimen subsets vs ABO group distribution in correctly grouped specimens (Figure 4 for example) suggested a slight bias in favor of obtaining a correct result with group O samples. One explanation for these results could be based on N-Ac-glucosaminidase and/or  $\beta$ -galactosidase activity in soil microbes, and we obtained some evidence for such activity.

DNA was isolated from bone tissue by standard phenol-chloroform extraction procedures. Figure 5 shows an autoradiograph obtained with a standard cocktail of MS1, MS31, MS43 and g3 probes after hybridization to southern blotted *Hinf*I restriction fragments (Jeffreys *et al.* 1985; Herrin *et al.* 1990) of blood and bone DNA from the same individual. Similar results have been obtained in RFLP analyses (Huang *et al.* 1990; Odelberg *et al.* 1990) using other restriction enzymes and probes. Similarly, amplification of specific DNA sequences by the polymerase chain reaction (PCR) (Erlich *et al.* 1988) in corresponding blood and bone specimens yielded comparable results in allele-specific tests for HLA-DQ $\alpha$  (Saiki *et al.* 1986) (Figure 6) as well as in amplification tests of the repeat sequence polymorphism 3' to the human APOB gene (Knott *et al.* 1986; Huang and Breslow 1987; Boerwinkle *et al.* 1989; Ludwig *et al.* 1989) (Figure 7).

The results of the extensive ABO typing study show that the combination AE/2DAI typing procedure is the

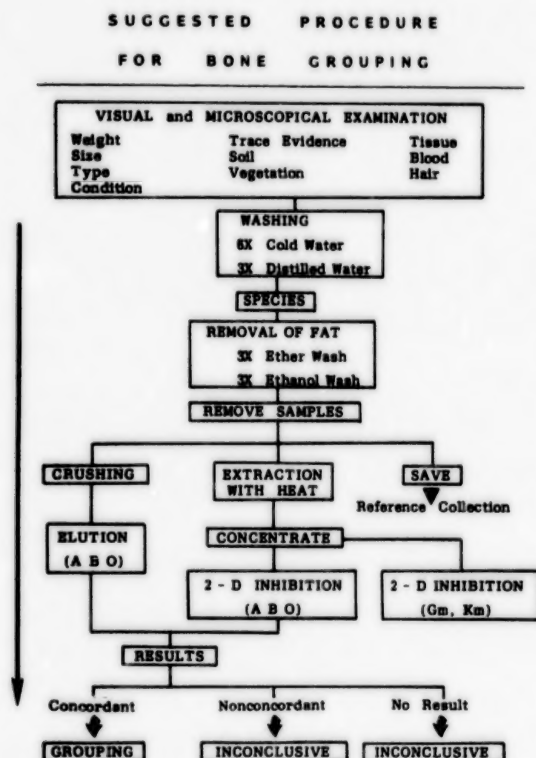


Figure 1. Overall procedure for bone specimen preparation, typing and interpretation of results.

### % INCORRECT RESULTS Aggregate

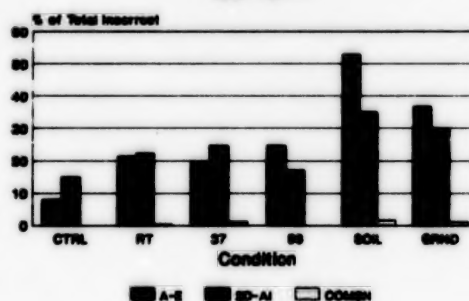


Figure 2. Percentage of total samples tested giving incorrect results by AE, 2DAI and combination methods according to environmental exposure condition. CTRL: Controls (no exposure to any condition and zero time).

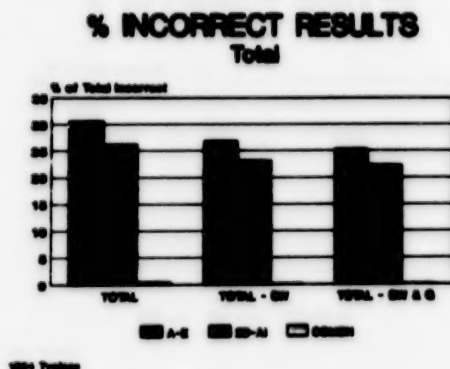


Figure 3. Percentage of tested samples tested giving incorrect results by AE, 2DAI and combination methods for all specimens, all specimens except those in wet soil, and all specimens except those in wet soil and buried in the ground.

most reliable method yet described for determining ABO types from human bone. The DNA isolation and typing results show that DNA suitable for RFLP analysis is obtainable from human bone tissue, that concordant patterns are seen in blood and bone DNA from the same individual, that bone DNA is suitable for PCR amplification and subsequent analysis for HLA-DQ $\alpha$  types using allele-specific oligonucleotide probes or analysis of

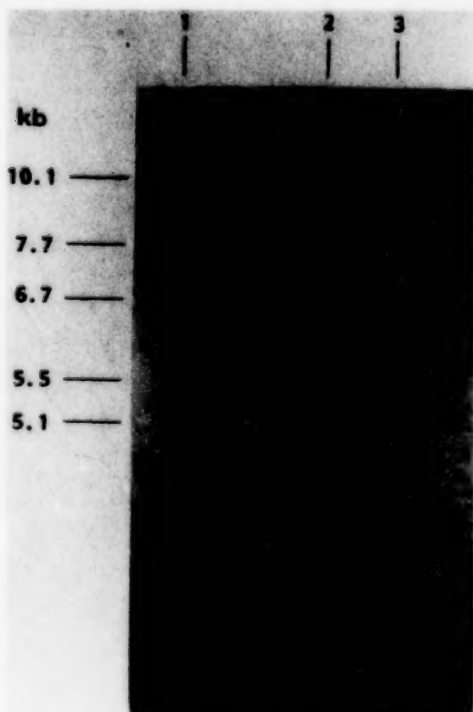


Figure 5. Autoradiograph of Hinfi fragments of blood (lane 2) and bone (lane 3) DNA of specimen 2019 after hybridization with a cocktail of Jeffreys' probes (see text); Lane 1, Known control DNA with approximate fragment sizes in KB indicated.

#### ABO Group Distribution Actual vs Correct - AE - TOTAL

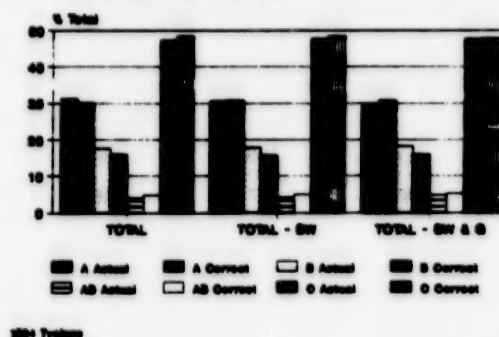


Figure 4. Distribution of ABO groups for all specimens grouped by the AE test vs distribution of ABO groups for all specimens grouped correctly by AE. Total - SW, and Total - SW & G have the same meaning as in Figure 3.

the 3'APOB repeat-sequence polymorphism using electrophoretic separation of amplified products and visualization with ethidium bromide.

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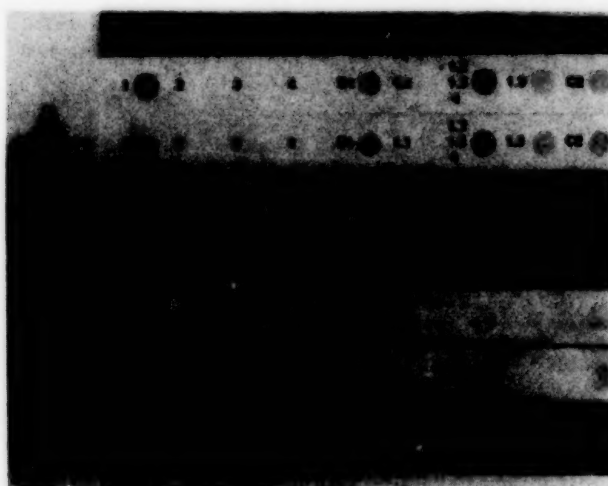


Figure 6. HLA-DQ $\alpha$  test strips (Cetus Corp., Emeryville, CA). Panel A: Blood (above) and bone (below) DNA of specimen 2042 (pattern corresponds to type 1.2, 1.3); Panel B: Blood (above) and bone (below) DNA of specimen 2281 (pattern corresponds to type 1.2, 2).

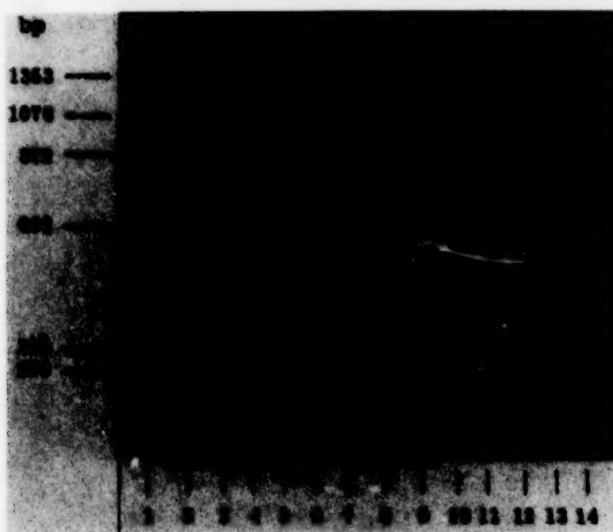


Figure 7. Ethidium bromide stained DNA fragments separated electrophoretically on 3% agarose after PCR amplification of the repeat-sequence polymorphism 3' to human APOB using the primers of Boerwinkle et al. (1989). Lanes 1,5,8,11,14, 500 ng HaeIII-digested  $\phi$ X174 DNA; Lane 2, K562 DNA (fragments correspond to 39 and 21 repeats); Lane 3 blood and lane 4 bone DNA of specimen 2001 (fragments correspond to 49 and 39 repeats); Lane 6 blood and lane 7 bone DNA of specimen 2006 (fragments correspond to 39 and 33 repeats); Lane 9 blood and lane 10 bone DNA of specimen 2004 (fragments correspond to 49 and 39 repeats); Lane 12 blood and lane 13 bone DNA of specimen 2002 (fragments correspond to 43 and 36 repeats).

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# SEQUENCING OF BLOODY SHOE IMPRESSIONS BY BLOOD SPATTER AND BLOOD DROPLET DRYING TIMES

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Although there are several facets to bloodstain pattern interpretation, very little attention has been devoted to the rate of drying of blood droplets and how this information might identify the period of time that an individual was at the crime scene (Laber and Epstein 1983; MacDonell and Bialousz 1973).

This work examined the rate of outer ring formation as a blood droplet dries. The degree of ring formation can be related to specific periods of time.

## MATERIALS AND METHODS

Freshly drawn human blood or anticoagulated whole blood at 37°C was released from a pipette or syringe tip onto a floor tile with a smooth non-absorbent surface. The height from which the blood was dropped was 1 m or greater. The blood droplets were blotted with a paper towel at various time intervals and the degree of ring formation was noted. Other droplets were tested by stepping on them with an athletic shoe at specific time intervals.

These studies were conducted within a temperature range of 16-27°C and a relative humidity between 40-89% over a 12 month period. Environmental factors were measured by a calibrated thermometer and hygrometer.

## RESULTS

Drying of blood droplet is first observed along the thin outer edge and forms a ring. It can be seen that the ring formation increases in thickness with time if the droplet is blotted or stepped on. If a person steps in blood within the first 50 seconds after the blood is shed, no ring will be formed. After the first minute to approximately 30 minutes, ring formation increases in thickness until the entire droplet has dried (Figure 1). In the first 15 minutes, temperature and humidity did not have any identifiable effect.

Studies performed in stagnant air were compared to those with sequential increases in air flow. Air flow will speed the drying rate after the first 10 minutes. This element had more influence on the drying rate than any other environmental factor observed within the limits of this study.

Comparison of drying rate (ring formation) with freshly drawn blood and ACD anticoagulated blood was identical. Therefore, coagulation or the existence of coagulopathies was irrelevant.

For smaller droplets, such as commonly observed in medium or high velocity blood spatter, the drying rate is much faster (Pex and Vaughan 1987).

## DISCUSSION

Experimentation has shown the difficulties which exist in the interpretation of blood spatter that has dried prior to being stepped on. This sequence cannot always be differentiated from a dried blood print with blood spatter over the top (Figures 2 and 3). Caution should be exercised whenever evaluating blood spatter on top of shoeprints especially if this is attempted from photographs (Eckert and James 1989).

An alternative approach that should be considered is the drying rate of blood droplets and evaluation of shoe prints were readily visible in the blood of the vic-

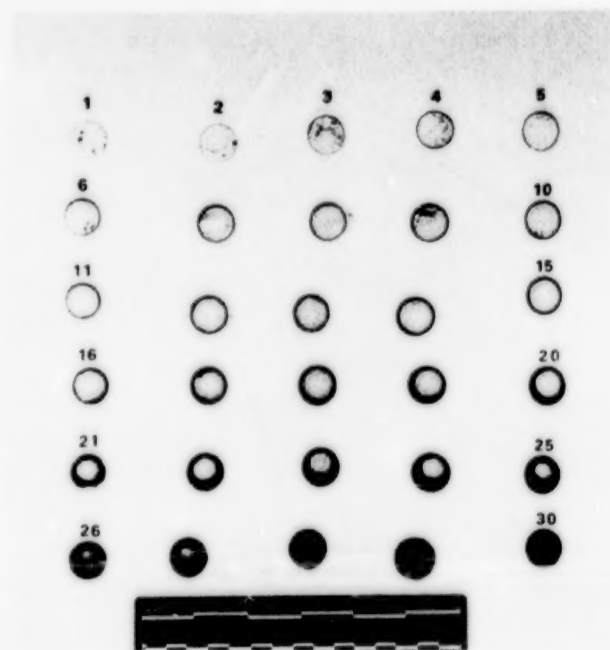


Figure 1. The rate of drying and ring formation for low velocity blood droplets over a period of 1 to 30 minutes. (21°C, 58% relative humidity, stagnant air flow).

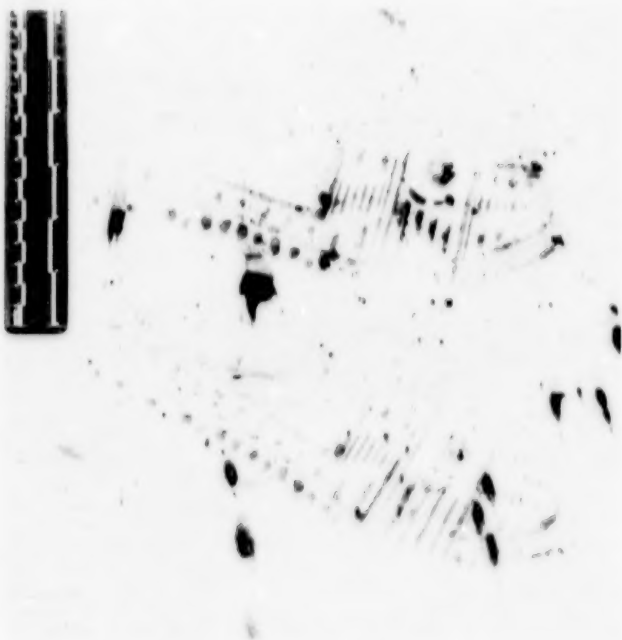


Figure 2. Bloody shoe prints over the top of dried blood spatter.

tim. Several low velocity blood droplets was necessary to determine whether the suspect was at the scene during the attack or a postmortem time interval existed previous to his arrival and discovery of the body.

In artificial environments created by modern climate control systems, very little fluxuation occurs in

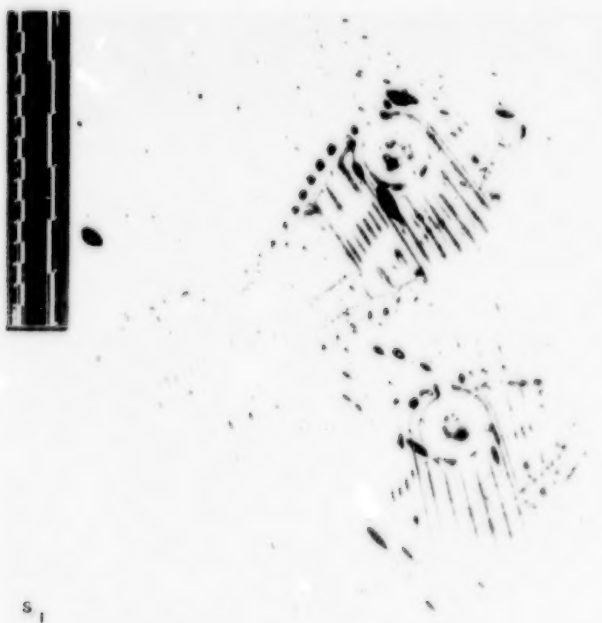


Figure 3. Blood spatter over the top of dried bloody shoe prints.

temperature, humidity or air flow, irrespective of changes in outdoor weather conditions. Therefore, it is possible to perform drying time/rate experiments and relate your findings to case evidence. If evidence is found at the scene as in Figure 4, an individual may be placed at the scene during the attack. The shoe prints were made immediately after the blood hit the floor. Reasonable environmental factors would have no effect upon this conclusion (MacDonell 1971).

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Figure 4. Photographs from crime scene showing blood droplets which have been stepped on prior to or just after start of ring formation.

## HUSBAND KILLS WIFE - EVIDENCE LEADS TO CONFESSION/CONVICTION

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On December 16, 1987, Wayne Gregory reported to the Thornton Police Department that an individual had attempted to burglarize his home. In the process the individual had entered the bedroom and stabbed his wife to death. Footwear impressions in the snow and a plastic trashbag of Christmas presents were found outside the home. A pair of workboots was found in a dumpster several blocks away.

The footwear impressions in the snow (recorded photographically) were examined noting style, size, wear, tread design (lack thereof), heel, stitching and a nail hole placement in the heel. Tests of the boots were made in a soft powder (Hydrocal). Test impressions were examined using the same methodology. The boots were found to have made the impressions in the snow.

The inside of the boot was examined and two hair/fiber strands were found plus the impression of the predominant boot wearer's foot. Through investigation and laboratory examination one fiber was found to be of the type used in hair augmentations (transplants). The husband (Wayne Gregory) was the recipient of such a hair transplant in Arizona. Contact with Gregory's doctor confirmed this information plus the doctor furnished hair standards. The other hair was consistent with the victim's hair.

The impression in the boot was examined using size, form, peculiar wear inside the boot, pressure, and foot angle measurements (Laskowski and Kyle 1988; Abbott 1964; Cassidy 1980). Two styles of boots belonging to the husband were submitted; cowboy style and workboot style. Foot impressions inside these boots were compared to the foot impression of the questioned boots. The foot impressions of all three types of boots were found to be entirely consistent with each other. This was sufficient to obtain further standards from Gregory. The exemplars and foot impressions were sent for

further examination to the FBI Laboratory where a more positive identification was reported.

The questioned plastic bag with the Christmas packages was examined for type of manufacturer, manufacturing marks, size, thickness, tears and colors (Von Bremen and Blunt 1983). The questioned plastic bag had green coloring on the outside with black coloring on the inside. It contained perforated tears on both sides of the opening with heat seal/out at the bottom. The plastic bag was compared with various manufacturing styles plus the manufacturer (Pace Warehouse, Glad Manufacturing) of plastic bags found in the house. All of the bags examined were eliminated except the bags from the house. The questioned plastic bag was found to be entirely consistent with the plastic bags in the house, as no individual characteristics were found.

The above evidence was testified to at a preliminary hearing, at which time Gregory admitted to killing his wife. At a district jury trial Wayne Gregory was found guilty of first degree homicide and sentenced to life in prison.

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## **OVERCOMING SOME OF THE COMMON PROBLEMS ENCOUNTERED WHEN USING A LASER FOR FIREARM TRAJECTORY DETERMINATION**

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Firearms are commonly used in homicides, suicides, accidental deaths and injuries. Many crime scenes are easy to interpret, but others may have been altered by the people involved or the rescue personnel. The investigator may want to reconstruct the scene to determine the validity of statements or to present the facts to a judge and jury.

A laser light is useful in visualizing the path of a bullet's flight. It can show the victim's and the shooter's perspective. It can trace a trajectory through intervening objects, show ricochets, or near miss situations. It can also help locate bullets which have passed through vehicles, houses, or bodies.

The laser light is invisible in clean air, but highly visible if particles are floating in the air. Fog from dry ice and water will fog a small area. Commercial fog machines are available (Edmund Scientific, Barrington, NJ) for approximately \$800. An alternative is "smoking" a large room by vaporizing ammonium chloride on an electric hot plate. Outdoor crime scenes can be "smoked" with law enforcement/military smoke grenades (Territorial Supplies, Inc., Morton, WA). Commercial signaling smoke candles (Cole-Parmer Instrument Co., Chicago, IL) are available which produce up to 100,000 cubic feet of dense zinc chloride smoke (and 1375 cubic feet of carbon monoxide).

The laser light can be photographed with any camera or low light video camcorder. Low light scenes give better contrast of the laser beam against a background. Any film can be used; however, a slow film requires a

longer exposure than fast film. Bracketing the exposure with an underexposed photo and an overexposed photo will help insure a usable picture. A dimly lit room can be illuminated with a separate flash during the time exposure. A 35 mm motion picture film 200 ASA #6271 will produce both a print and a slide (Seattle Filmworks, Seattle, WA). If black and white photographs are needed, Agfapan Vario-XL ASA 125-1600 is very useful. The laser will appear as a white light, necessitating a dark background for contrast.

The laser light beam is five times brighter when pointed toward the camera than it is when pointed away, increasing the ability to photograph the beam. In many situations, the laser can be mounted on a photographic tripod pointing toward the camera. Flower shop "stickem" mounting medium, on the back of the mirror, will attach it to the background and facilitate adjustment. It is available at floral and hobby shops. The mirror can be mounted on the muzzle of a firearm, which gives the illusion that the laser beam is coming from the barrel. If it is mounted on a mannequin, dressed in the victim's clothing, it can appear that the beam is travelling into the bullet wound. A mirror can also graphically reproduce the trajectory of a ricochet. With a little practice a laser light can give an impressive, professional, high-tech quality to court demonstrations and crime scene reconstruction.

A comment on safety would be appropriate - Do not look into the laser light. Adequate eye protection and breathing apparatus should always be used.

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# TRAJECTORY RECONSTRUCTIONS AT CRIME SCENES USING LOW POWER LASERS AND POSITIONING STAGES

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Properly executed trajectory reconstructions can be of inestimable value in casework. They can provide pivotal evidence in deciding among competing scenarios about what took place at the crime scene (Petraco and De Forest 1990). Of course, as in any reconstruction work, a thoughtful, detailed, and even elegant, reconstruction may yield details which may not be of key importance in the particular case. On the other hand, in some cases, a simple reconstruction may be adequate to resolve important issues. Despite their importance, trajectory reconstructions continue to be misunderstood, misapplied and under-utilized. Serious consequences in casework can result from a failure to understand the basic principles. Of paramount importance is knowledge of how to accurately establish a trajectory and an appreciation of factors influencing deflection.

Several geometric methods for trajectory determination are available to the forensic scientist at the crime scene. These include physical projection methods (probes, rods and strings) and optical projections methods such as sighting, use of theodolites and low power lasers. All are useful as demonstrative aids and in varying degrees, analytical tools. The low-power laser is the single-most versatile of these. The use of such low-power lasers in combination with remotely controlled positioning heads is the subject of this paper.

The use of low-power lasers for establishing trajectories at crime scenes was first discussed several years ago (De Forest *et al.* 1983). More recently the technique has been taught in forensic science workshops. Despite the fact that this is clearly the single-most versatile projection method in the armamentum of the crime scene scientist, it is used relatively infrequently. Other than a possible general lack of awareness, the reasons for this underutilization are unclear. The cost of a suitable low-power helium-neon or gallium-arsenide laser is relatively modest, and the principles of use can be elaborated quite simply. Both one and two-port lasers can be

useful. It is convenient if the laser has a standard tripod socket mount, although other means of mounting the laser can be devised.

Accurate documentation of the trajectory ascertained by use of the laser beam can be obtained in a variety of ways. Photographic tripods often appear to lack the requisite rigidity and stability for serving as a positioning platform for the laser. The pressure of manual contact with such a tripod to effect adjustments in position or orientation will produce wild deflections of the beam making it seem impossible to obtain the necessary increasingly refined adjustments. The beam will move again when the hand pressure is released. However, even with such a seemingly crude device fairly rapid alignment is possible by trial and error. If the laser head is mounted on a multi-axis stage with linear and degree graduations, its position and orientation can be read from the scales on the stage. Such stages are quite expensive and must be positioned and oriented accurately relative to the scene prior to being aligned with bullet holes. For these reasons they are somewhat cumbersome for crime scene work. Suitably accurate, simpler alternatives are available. A simple, stage, although less than elegant in appearance, can be made from two rack-and-pinion or worm-drive focussing rails and two rotary positioning stages. Remotely controlled electrically driven devices provide distinct advantages. A simple device can be made by combining the focussing rails with a commercially available, electrically driven, photographic pan/tilt head.

In any attempt at trajectory reconstruction the possibility of deflections must be taken into account. In the situation where a bullet passes through an object, it is prudent to assume that the interaction would result in some degree of deflection. However, it may not be clear whether such passage results in significant deflection. It is necessary to consider the nature of the object, its geometry, and the way in which the bullet interacted

with it. A number of factors can be enumerated which can influence the degree of deflection (Table 1).

Although two points can be used to establish a trajectory, this minimum number of points is clearly not adequate unless it can be shown that the degree of deflection is negligible (Haag 1987). With three or more points contributing to knowledge of the trajectory, the problem of assessing the degree of deflection may become trivial.

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**Table 1. FACTORS INFLUENCING DEFLECTION.**

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Intermediate target properties

- hardness
- surface features
- degree of internal heterogeneity
- directionality of internal heterogeneity
- thickness, compliance, elasticity

Projectile properties

- hardness
- shape
- mass
- mass density
- cross-sectional area
- cross-sectional density
- velocity
- flight stability

Angle of flight path relative to target surface

- entry surface
  - exit surface
-

## **HOMICIDE RECONSTRUCTION WITH THE USE OF SCALE MODEL FOR COURTROOM PRESENTATION**

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The courtroom presentation of evidence is vital to law enforcement, and must be done in the most thorough and professional manner possible. Conventional methods of visual evidence presentation includes photographs, diagrams and video tapes. However, to ensure a verdict consistent with the facts and evidence in more complex cases, the investigator must be creative in reconstructing the crime. One way to simulate the crime scene is through the use of scale models. The ultimate success and validity of scale models is proportionate to the pre-planning. Planning for an endeavor of this type should begin with the moment an investigator enters the boundaries of the crime scene. While processing the scene, from the first photograph to the final sketch, attention must be directed to details necessary for later reconstruction. Essential preliminary components are video tapes and a complete set of photographs of the crime scene. Other documentation should include carefully measured sketches and a set of blueprints. When using blueprints, care must be taken to ensure that they accurately reflect the crime scene at the time of the incident.

Another invaluable tool is a quality paint chart. This chart lists wall colors from each room of the scene. A reference chart of the actual colors is extremely important due to the possibility of color changes when the photographs are printed. The chart will allow reproduction of the walls as close as possible to the original scene. The investigator should also obtain the services of a city engineer willing to lend his expertise to the project. Prior to construction, the prosecutor should be consulted to determine the scope of the model. In most cases, a complete model is necessary. Visual models hold the attention of the jury as evidence is introduced

and can be a valuable aid throughout the trial. Cost is always a factor when operating on a limited budget. However, it may be possible to split the cost between your agency and the prosecutor's office. When you consider the overall cost of a major trial, the cost of a model is minimal. Remember, accuracy is the key when reconstructing. A scale of one inch to one foot is an excellent ratio for most models. If the model has more than one floor, construct one floor at a time. Double check each measurement before cutting or gluing. As each room develops check furniture and evidence to insure proper placement and scale. If there is an omission of a wall or furniture, it should be noted symbolically by lines or markings. When using lines to indicate bullet travel, florescent markers can transform a plain white string into a piece of evidence that will stand out from the remainder of the model. The use of scale models has been used affectively in private practice for many years with excellent results. As stated earlier, a scale model will assist the prosecution in several ways: it will reconstruct the scene in a three dimensional manner and enable the jury to view it as it appeared at the time of the incident; it will allow witnesses to walk through the scene and enable them to visually relate incidents as they are explained; it will limit the ability of the defense to confuse the jury when the scene is in front of them; and can easily be moved to the deliberation room for use as an aid by the jury.

A carefully reconstructed crime scene model is very impressive. When supplemented with quality photographs, diagrams and video tapes, the jury can accept the accuracy of the exhibits presented during the trial.

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# HOMICIDE RECONSTRUCTION FROM GRAVESITE AND SKELETAL REMAINS EXCAVATION EVIDENCE A CASE STUDY

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The careful execution of gravesite excavation and skeletal remains recovery are critical first steps to the successful resolution of buried body cases. Initially, all such cases should be handled as homicides (that is, with the utmost care, thoroughness and documentation) until it is known to be otherwise. Gravesites are rarely the scene of the crime. It is the gravesite, the body remains, and all the items associated with the grave or body that must be evaluated for potential evidentiary value in terms of reconstructing the events leading to the death and burial, dating of the event, determining the cause of death and the identification of the victim and/or suspect. Yet, frequently these buried body cases are handled with more haste than would be used to process other conventional crime scenes. The following case study was presented to be demonstrative of the techniques, thoroughness and team efforts advocated for use in buried body cases.

In 1987 while reinforcing a foundation, a construction crew initially unearthed human skeletal remains six inches below a sidewalk adjacent to a 40 plus year old house. An investigative team continued the excavation in a manner akin to an archaeological dig over the next two days revealing a complete, supine, clad female skeleton partially encased in cement. The cement encasement was different than the overlying sidewalk cement. The apparent bottom boundary of the grave, some 20 inches below the surface, was lined by outstretched clothing.

The most important techniques employed for the excavation and remains recovery included:

- 1 — Methodical excavation predominantly using hand tools (whisk brooms, trawls) with photographic and written documentation;
- 2 — Packaging of bones for transport in non-plastic, separate containers with appropriate cushioning;
- 3 — Sequential sifting of all dirt removed from the grave (using a custom-made set of

nested screens of 3 mesh sizes tripod mounted);

- 4 — Metal detector sweepings of all sifted dirt and throughout the grave area. Although this approach is time consuming, it will ensure that all remains (skeletal and other) are recovered, prevent damage to the skeletal remains which may be misinterpreted as trauma or obscure interpretation of trauma, and give reliance to what was not found associated with the grave.

A cigarette pack, clearly found within the grave above the lower boundary but below the body, was identified as a test market product issued for a limited time in 1974 allowing approximate dating of the grave to some 14 years earlier. Tree roots and toys within the gravesite could also be used for approximate dating.

Toolmarks located on the recovered bones showed the deceased to be the victim of multiple stab wounds to the head and neck. X-rays subsequently located a metallic object embedded in one of the toolmarks which upon removal appeared consistent with a knife blade tip. Additional toolmarks on some finger bones suggested defense wounds to the hand. A knife was not recovered in the grave area, but due to the extent of at site processing, the investigators were confident a knife was not missed.

The cement encasement had apparently been poured over the victim soon after death. It contained a negative impression of the victim's upper body including the face and right hand. Silicone-based polymers were used to make positive casts of the face and hand. A drawing of the face and fingerprints from the handcast were used to identify the victim. The face and hand impressions showed corroborative evidence of the stabbing and defense wounds by the cement having preserved the soft tissue trauma.

Following the successful identification of the victim, the determination of cause of death and the dating of the incident, a suspect was arrested.

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# TECHNIQUE OF FACIAL RECONSTRUCTION DRAWING

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Forensic facial reconstruction, the technique of approximating the facial appearance of an individual in life, based primarily on bony evidence of the skull, is accomplished for the purpose of aiding in individual identification. This art/science can be utilized in cases of persons whose features are decomposed, charred, distorted by physical trauma semi-skeletal, skeletal, or otherwise unrecognizable. Well known and successfully used by various forensic artists is the 3-D clay technique popularized by Gatliff (1984).

Less explored is reconstruction done by 2-D techniques or facial reconstruction drawing. A new method developed at the Texas Department of Public Safety over the past five years has aided in numerous identifications. In previous methods of 2-D reconstruction using tracings over skull photographs, full use of available soft tissue thickness data was very difficult, particularly in the frontal view since the reconstructionist had to apply data developed from the 3-D head to the 2-D skull photograph.

The alternative procedure herein suggested involves gluing tissue depth markers directly on the skull (as for 3-D reconstruction), then photographing the skull and preparing life-size prints. The artist can then sketch the facial features with the advantage of incorporating a greater percentage of the data as developed by various

anthropologists and other science professionals. The camera, in effect, does the work of appropriately fore shortening the facial planes as it would do when a living face is photographed.

## METHOD

Certain preliminary information should be gathered and evaluated. It is recommended that the process be treated as art/science and approached as a team effort. Ideally, the artist should work side by side with the scientist, particularly the forensic anthropologist. Common sense dictates that the more material recovered at the scene as well as the manner in which it is recorded and preserved may directly affect the odds that a facial reconstruction technique will be effective. Similarly, the amount and quality of information provided by the anthropologist, pathologist, odontologist and other forensic scientists may directly affect the accuracy of the finished reconstruction. Data provided by these specialists concerning race/sex must be used to determine the appropriate tissue depth approximation charts (Gatliff 1984). Laboratory examination of hair specimens and clothing when available can also provide useful information. The mandible is glued to the cranium of the



Figure 1. Hispanic female: skull, reconstruction drawing, subject identified.

cleaned skull, with consideration given to occlusion of the teeth as well as spacing in the jaw joint. Cylindrical tissue depth markers of rubber eraser material are cut to correspond to the tables of average tissue thicknesses according to race/sex. These markers are then glued to the skull at various landmark locations. The skull is photographed frontally and laterally with a 35-105 mm lens to minimize distortion, with a scale included to facilitate preparation of 2.5 X 2.5 cm prints. The life-size photos are oriented in the Frankfort Horizontal, and semi-transparent drawing paper is placed over them, allowing for constant viewing of the skull beneath. It is recommended that the skull itself also be on the drawing table for easy referral. Frontal and profile drawings are done simultaneously, working back and forth, one to the other, so that information derived while developing the profile drawing is incorporated into the frontal drawing, and vice versa. (Note: The right profile is used for possible future comparison with mugshots which are traditionally taken from the right side...should the deceased have had a criminal record). Any associated eyeglasses, articles of clothing, headgear or jewelry recovered at the scene should be included in the drawings if possible. Also any body weight determinations gleaned from these articles should be noted and drawn accordingly, otherwise the individual must be depicted at an average weight. Hair should be sketched after viewing any specimens that are available and assessing color, length, texture, volume, and wave quality. Hairstyle must generally be guesswork and is often drawn in an intentionally ambiguous and nondescript manner. Clues to hairstyle may be gained from the age, clothing, life-style, etc., of the

deceased. In drawings of males, it is simple to produce several variations showing more or less facial hair. Eye color can usually only be speculative, but consideration should be given to the hair color of the individual and to statistical probabilities for eye color within racial groups. Most important of all is the manner in which individual facial features are developed. Various formulae for determination of specific features have been put forth in the literature (Krogman 1962; Stewart 1983; Gatliff 1984; George 1987). Especially notable is the material by George (1987) because of the extensive incorporation of anatomical data and the obvious recognition factor that is achieved in the completed lateral test drawings. In some instances, facial photo references may be used; although, great caution should be taken to avoid undue influence. For example, photos of persons with buck teeth can be used for guidance into the way the lips tend to form around such dentition. Continual in sight can be gained by observation of living human faces and by review and assessment of new studies regarding individual feature development.

## RESULTS

Upon completion of the drawings, media distribution is made to an extent usually determined by the requesting officer or agency. Numerous variables exist such as: amount of media coverage, quality of media reproduction of drawings, and availability and willingness of associates or relatives to recognize drawings and contact authorities. Despite the rather large obstacles, reconstruction drawings developed in this manner have



Figure 2. White male: skull, reconstruction drawing, subject identified.

led to numerous identifications of unknown deceased persons. Figures 1 - 4 show forensic cases in which positive results have been achieved. Shown are comparison photos of the skull, frontal drawing and person identified in each instance.

### DISCUSSION

While it is virtually impossible using previous means to measure and convert 3-D tissue depths to the 2-D

format in the frontal view, it is a simple matter for the camera to make these conversions when the method herein described is used. By first gluing the tissue depth markers on the skull, then photographing it, the artist can speculate upon the planes of the face with the benefit of a greater usage of the information which science has provided. For this reason, this technique is a viable alternative means of facial approximation that can lead to identification in cases of natural, accidental, or intentional death.



Figure 3. White female: skull, reconstruction drawing, subject identified.



Figure 4. Black male: skull, reconstruction drawing, subject identified.

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# UTILITY OF FACIAL RECONSTRUCTION AS AN AID TO IDENTIFICATION OF SERIAL MURDER VICTIMS

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Forty-one victims of the Green River Killer have been recovered. Following failure of traditional means to identify 9 of these victims, 24 facial reconstructions were used in efforts stimulate leads for identification. Nine different artists were used.

The techniques employed included 3-D clay sculptures using the victim's skull or a model of it (Krogman 1946; Rhine and Moore 1982; Snow *et al.* 1970; Gatliff 1984; Rathbun 1984), and 2-D drawings based on photographs or X-rays of the victim's skull (George 1987). Information provided to the artist included the anthropological assessment of race, sex, age range, stature, approximate date of death and, if known, hair length and color. Dependent upon the artist's preference and demands of technique, the actual skull, model of skull, X-rays or photographs of skulls were provided.

Table 1 lists the date of the victim's discovery and identification (if identified), artist, type of reconstruction, current ID status and, in cases of identified victims, the information which provided the positive lead to identification.

Although five of the reconstructed victims were subsequently identified, leads resulting in their identity were triggered by other than reconstruction efforts (Table 1). In three of these identifications, media accounts, usually during media coverage of other discovered victims, prompted reports of previously unreported missing victims. One report of a hip fracture in the media caused a fourth case to be reported missing. Police investigators discovered the individual identified in the fifth case was missing while doing routine follow-up aliases of another Green River Victim.

**Table 1. RECONSTRUCTION EFFORTS FOR GREEN RIVER VICTIMS.**

Case	Date Discovered/ Identified	Artist	Reconstruction Effort	Lead to ID Generated by
1	1 Aug 83/20 Oct 84	A	Clay Reconstruction	Reported Missing
2	19 Sep 83/22 Feb 85	A	Clay Reconstruction	Hip Fracture
		B	Clay Reconstruction	To Media
3	29 Oct 83/05 Dec 84	B	Clay Reconstruction	"Blond" hair of another unidentified reported to media
4	Human Remains #10 22 Mar 84/?	B	Clay Reconstruction	UNIDENTIFIED
		C	Drawing from X-ray	
		D	Drawing from skull photo	
		F	Clay Reconstruction	
		G	Clay Reconstruction	
		H	Drawing from skull photo and X-ray	
5	20 Apr 84/01 Jul 88	C	Drawing from X-ray	Alias Follow-up
6	Oregon #2	D	Drawing from skull photo	UNIDENTIFIED
	23 Apr 85/?	E	Clay Reconstruction	
7	23 Apr 85/07 Mar 88	D	Drawing from skull photo	Reported missing
		E	Clay Reconstruction	
8	Human Remains #16 30 Dec 85/?	C	Drawing from skull X-ray	UNIDENTIFIED
		D	Drawing from skull photo	
		E	Clay Reconstruction	
		G	Clay Reconstruction	
		H	Drawing from skull photo and X-ray	
		I	Clay Reconstruction	
9	Human Remains #17 30 Dec 85/?	D	Drawing from skull photo	UNIDENTIFIED
		E	Clay Reconstruction	

Difficulties in identification of Green River Victims have been reported elsewhere (Haglund *et al.* 1987; Rothwell *et al.* 1989). It is likely that lead-gathering potential of reconstructions may be higher when unidentified individuals are older, more established in the community and drawn from smaller population base. An analysis of such factors is needed.

Facial approximations have not been successful in stimulating leads to identifications in the Green River Investigation. They continue to be used, in the main, to advertise for new missing individuals to be reported. These techniques provide powerful attraction to the media. Only time will reveal the utility of reconstructions of the four yet unidentified Green River Victims.

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## **MAPPING AND PLOTTING OF PHYSICAL EVIDENCE CONDUCTIVE TO ACCIDENT/DEATH SCENES DEVOID OF PERMANENT LANDMARKS**

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The accurate mapping and placement of physical evidence in the investigation of accident/death investigation scenes is crucial to subsequent reconstruction of the scene as well as understanding the physical dynamics involved. The common methods of triangulation and grid pattern documentation, do not render themselves useful when the scene is in a remote area free of fixed datum points or land marks. The following techniques renders itself useful and accurate in the mapping and plotting of evidence in a remote scene.

The initial step that needs to be taken is the placement of the fixed datum point from which all measurements and calculations will be made. The placement of the datum point will be a personal choice germane to each scene. The datum point should be offset at least 20 feet from the most concentrated area of physical evidence so as to take advantage of distance to determine proper compass bearings. In crime scenes which cover a large land area such as aircraft and rail accidents, it is practical to have more than one datum point to facilitate the incorporation of all physical evidence into the diagram. It is important to note that each datum point must be plotted and surveyed in relation to each other. When each item of physical evidence is located, the distance measurement and compass bearing will be made of the evidence as it relates to the datum point. This is accomplished with the use of a surveyors' compass (Florida Level and Transit, Orlando, Florida), placed on a tripod directly over the datum point along with a tape measure or accurate optical range finder (Florida Level and Transit, Orlando, Florida). Subsequently, a temporary evidence marker will be placed at the location of the item of evidence. Should there be a highly concentrated area of

evidence at the scene, it is preferred that a square grid be constructed using wooden dowels and twine to facilitate this. The grid itself can then be plotted on the diagram using the aforementioned technique by locating it's four corners. Evidence may then be located and plotted in the appropriate portion of the grid. A complete legend of all physical evidence must be constructed to show distance from the datum point, compass bearings, and height should the item of evidence be on a different elevation than the datum point. Evidence of dynamic activity such as skid or yaw marks may have numerous entries on the legend to accurately document movement. The diagram can be constructed at a later time, and should contain physical and topographical information such as vegetation, water and etc. Once the scene examination is complete, the datum point must be located by an accurate survey, usually by a professional surveyor. The datum point, made out of metal such as an iron pipe, should be driven into the earth below grade level which will allow for future location with a metal detector. True north must be illustrated on the diagram along with the datum point, and all physical evidence with item numbers plotted using a 360° protractor, positioned according to true north on the diagram. The diagram legend should be placed on the diagram along with other biographical data relating to the case such as case number, location, and author of the diagram.

The technique just described has been applied to numerous death investigation scenes ranging from found skeletal remains to multiple victim's of serial murders. Several of these crime scenes have been either wholly or partially reconstructed years after the initial investigation, with great success.

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## THE IMPORTANCE OF DENTAL EVIDENCE IN SCENE INVESTIGATION

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Dental evidence can be of crucial importance in the investigation of disasters and crime scenes because the teeth are the most durable part of the human body, and are unique to the individual. This paper describes the wide range of application of dental evidence by presenting three very dissimilar examples of its use. Benefits, as well as pitfalls, are emphasized.

Following a massive investigation, Richard Ramirez was tried in Los Angeles for 13 murders and 30 other felony counts. The defense claimed that Ramirez could not have committed some of these crimes because they occurred in Southern California at a time that he was in El Paso. However, the prosecution introduced two surprise witnesses in rebuttal, both dentists. One, a forensic dentist, testified that he had examined radiographs (X-rays) of a Richard Mena, known to have received dental treatment in Los Angeles during the dates in question. These films were compared to X-rays taken of Richard Ramirez after capture. The dental X-rays proved that Richard Mena was, in fact, Richard Ramirez. This proved that Ramirez was in Los Angeles on the crucial dates and destroyed his alibi.

Also in the Ramirez case, dental X-rays were used as the basis for a drawing of the suspect's teeth during the manhunt. This provided a more accurate picture of the suspect's appearance than an earlier drawing based on eyewitness descriptions. Additionally, photographs of Ramirez teeth were introduced in evidence to help the

jury analyze conflicting statements by witnesses about the appearance of their attacker.

Another example of the use of dental evidence occurred when 82 persons died in the worst disaster in the history of Los Angeles International Airport. This crash differed from some others in that the aircraft fell more than 6,000 feet, resulting in extreme fragmentation of the bodies. Of the 69 victims identified, 40 were identified by dental evidence, including 16 who were also identified by other means. A lesson learned from this, and other disasters, is that it is extremely important to involve dental personnel in the disaster scene search, as well as at the identification center.

Evidence of human bite marks, particularly in murder, rape and child abuse cases, can be crucial in placing the suspect at the crime scene. However, serious error can occur when the reported bite marks are actually something else. In two such cases, it was learned fairly early that EKG pads had been placed by paramedics, causing abrasions closely resembling bite marks. In a third case, however, the prosecution used bite mark evidence to help support a child abuse-murder charge against a mother. Significant problems arose when other experts later determined that the bite mark was really a postmortem abrasion, probably caused by medical apparatus. Such marks tend to be more superficial than bite marks, with little or no bleeding subcutaneously.

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# RECONSTRUCTION OF A QUADRUPLE DEATH SCENE

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On July 10, 1989, the Hartford Police Department responded to a death in an affluent section of town. Upon initial observation of the incident scene, four members of the family in residence were all found dead from some form of gunshot wounds. At the request of the Chief State's Attorney and the Hartford Police Department, members of the Connecticut State Police Forensic Science Laboratory were requested to assist with the reconstruction of the scene and events leading to the deaths of the four individuals. This investigation had five main areas of focus.

## SCENE

No signs of forced entry were located. The scene was found to be consistent with an organized and planned type. The four bodies were located in two second floor bedrooms and the family pets were still in the home. Suspected weapons were both located next to the oldest male victim's body.

## RECONSTRUCTION

Documentation of the scene was completed after preliminary viewing and assessment. The bloodspatters located near each victim were consistent with high velocity type spatter. A determination was made that all victims died at or near their final locations by the distribution of the high velocity impact type of bloodspatter. The scene was searched and physical evidence collected for further laboratory analysis.

## EVIDENCE

The blood groupings and iso-enzymes results indicated that they originated from the four victims. No foreign blood sources were identified. Bullets removed from John III, Julie and Anna, exhibited characteristics consistent with Winchester-western silver tip projectiles observed in a Colt Python .357 magnum at the scene. Examination of John Jr. showed he received a single shotgun wound to the mouth with exit through the top of his head. The spent casing was linked to a 12 gauge Remington shotgun recovered next to his body. A .357 Colt Python was also located at this location. Atomic absorption swabs and scanning microscope disks were collected from all victims, then analyzed. Lead, barium and antimony were found only on John Jr.'s hands.

## ENTOMOLOGY AND AUTOPSY FINDINGS

The preliminary and later autopsy examination revealed three persons had died of cranial gunshot wounds and the fourth by a single shotgun injury to the mouth and the head.

John III, Julie and Anna all died as a result of close contact range gunshot wounds. John Jr. died as a result of a single shotgun wound to the head. Entomological samples were taken from both the scene and the deceased to help in determining the time of death. Preliminary inquiries suggested that all had met their deaths approximately five days prior to their discovery. A comparative analysis of insect specimens revealed that two

of the victims (Anna and Julie) had died five days prior to their discovery and that the other individuals (John Jr. and John III) had perished three days later. Subsequent investigation verified the entomology findings.

#### **WITNESS STATEMENTS**

Witness statements were taken by the Hartford Police Department and by interviewing various people. We learned that John Jr. was observed on Friday, July 7, 1989. Checks with family and friends revealed John Jr. to be a caring and charming family man. Attempts to track the whereabouts of the two younger children met with limited success. It is believed that John III (son) returned home on or about July 7th. Anna (mother) was last observed on July 6th and Julie's (daughter) arrival at

the family home is still uncertain. At the scene various notes from John Jr. were located showing possible motive for the crimes.

#### **CONCLUSION**

Based on the five proceeding areas of focus the following facts related to this case could be reconstructed. The incident scene was found secured from the inside and relatively undisturbed. All victims died at or close to the positions their bodies were found. The bloodspatter patterns and the positions of the victims were undisturbed and unaltered. No indications of any other person's involvement were noted. All of the patterns and physical evidence indicate John Jr. killed Julie, Anna and John III and subsequently committed suicide.

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